East Engin.
Library

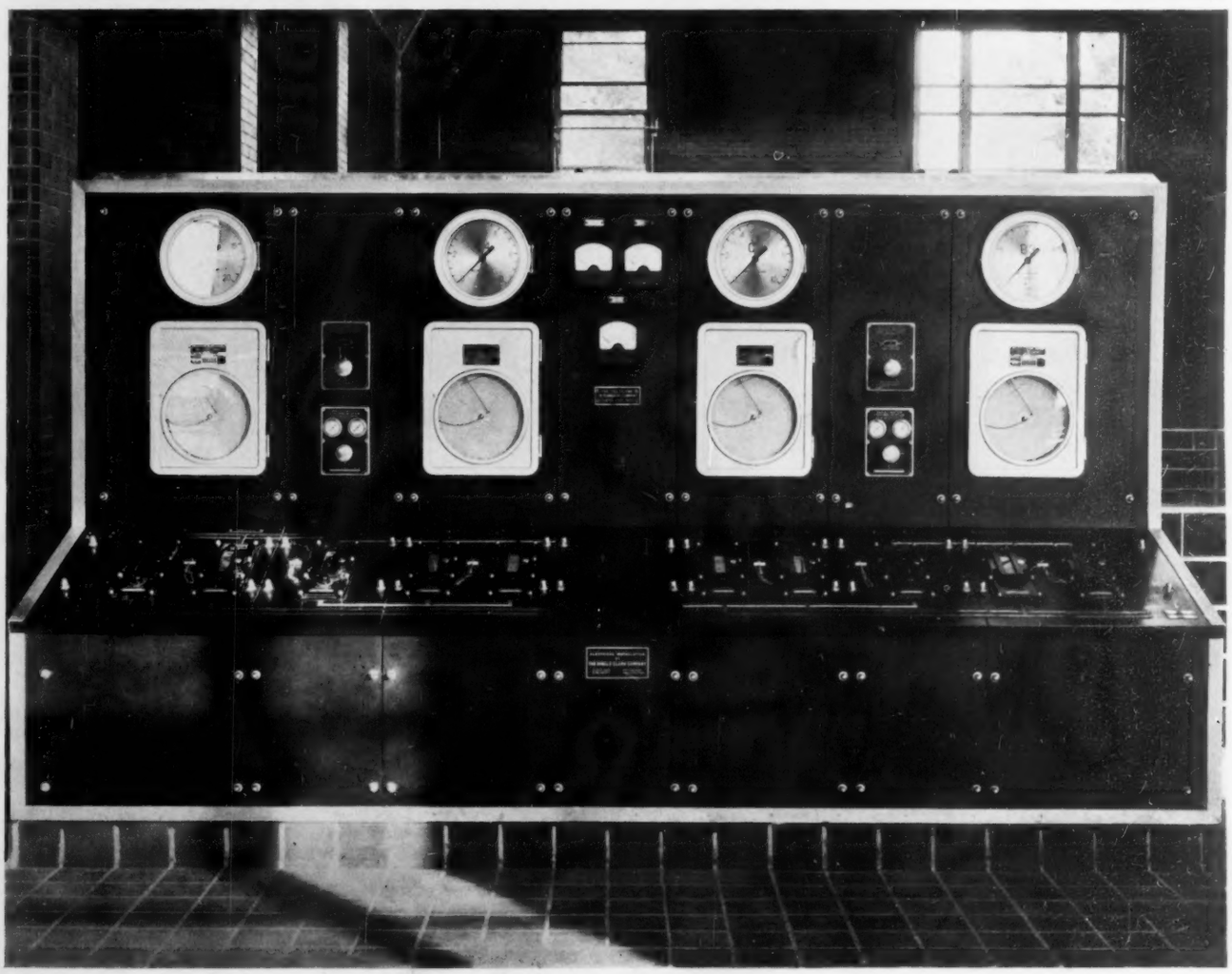
JAN 23 1935

INSTRUMENTS

THE MAGAZINE OF

MEASUREMENT AND CONTROL

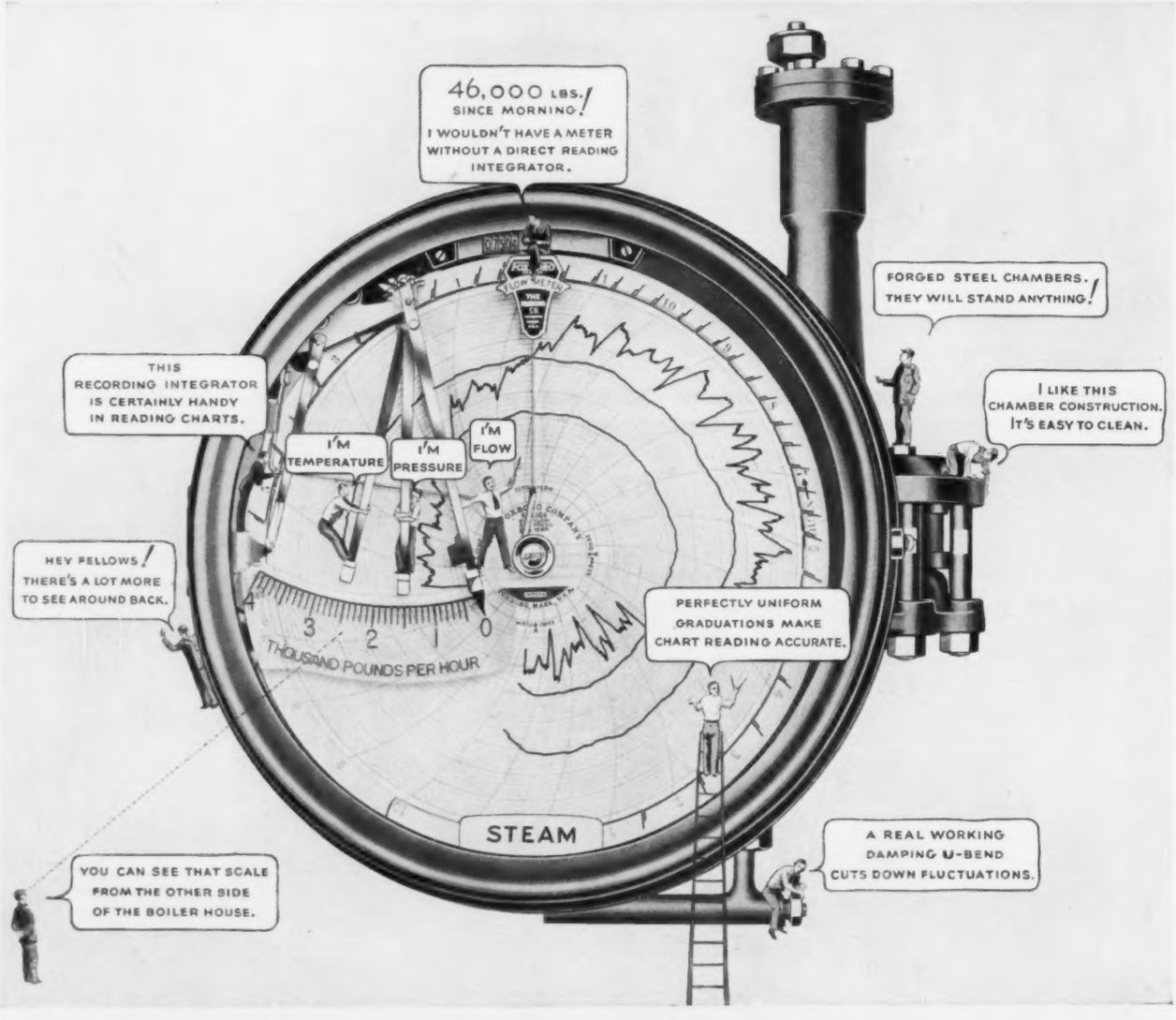
Volume 8 JANUARY 1935 Number 1



AN AMERICAN BOILER CONTROL INSTALLATION IN FRANCE—SEE PAGE A4

(Courtesy Bailey Meter Co.)

THIS NEW METER FITS ALL INDUSTRIAL FLOW CONDITIONS


46,000 LBS.! SINCE MORNING!
I WOULDN'T HAVE A METER WITHOUT A DIRECT READING INTEGRATOR.
FORGED STEEL CHAMBERS. THEY WILL STAND ANYTHING!
THIS RECORDING INTEGRATOR IS CERTAINLY HANDY IN READING CHARTS.
I'M TEMPERATURE
I'M PRESSURE
I'M FLOW
I LIKE THIS CHAMBER CONSTRUCTION. IT'S EASY TO CLEAN.
HEY FELLOWS! THERE'S A LOT MORE TO SEE AROUND BACK.
PERFECTLY UNIFORM GRADUATIONS MAKE CHART READING ACCURATE.
THOUSAND POUNDS PER HOUR
STEAM
A REAL WORKING DAMPING U-BEND CUTS DOWN FLUCTUATIONS.
YOU CAN SEE THAT SCALE FROM THE OTHER SIDE OF THE BOILER HOUSE.

Here is a truly universal meter that will measure the flow of any fluid under any industrial condition.

You can have a simple Recording Meter, or if conditions require, you may have

1. Pressure Compensation.
2. Direct Reading Integrator.
3. Recording Integrator.
4. Pressure Recording Pen.
5. Temperature Recording Pen.

Of course, this meter meets every power plant requirement! It is also the perfect meter for steam distribution, gas and water systems. It will pay you to get the complete story on the Foxboro Universal Meter. Write today, no obligation.

FOXBORO
REG. U. S. PAT. OFF.
THE COMPASS OF INDUSTRY

THE FOXBORO COMPANY, FOXBORO, MASS., U. S. A.

Branch Offices in Principal Cities

• • COMPLETE INDUSTRIAL INSTRUMENTATION • •

INDEX TO
INSTRUMENTS
THE MAGAZINE OF MEASUREMENT AND CONTROL

Volume 8

Published Monthly on the 15th by
The Instruments Publishing Company
1117 Wolfendale St., Pittsburgh, Pa.

SUBJECT INDEX

January 1-28
February 29-56
March 57-84
April 59-110
May 111-138
June 139-166
July 167-196
August 197-226
September 227-250
October 251-282
November 283-316
December 317-348

Accelerometer, Air-damped 5
Aircraft Instrument, Proposed Vacuum-tube Type of "True Direction" 116
Aircraft Instrument, Relativity's Reality Foils Attempt to Design "True Direction" 30
Air Velocity Indicator, Duct Jet, Attachment for. 343
Altitude Records are Certified, How 86
Amplifier, Combination 104
Anemometer, Direct-reading 191
Apparatus for Mounting Microscope Specimens... 108
Attenuator, P. A. 343
Balance, Portable 280
Bi-metallic Thermal Elements 305
Blueprinter 52
Blueprinter, Floor Model 249
Boiler Control, Simplified Unit-constructed 83
Brake Performance, Instruments Contribute to Better 140
Brinell Attachment, Direct-reading 52
Brinell Tester, Direct-reading 306
Calculator for Radio, Wire Data, etc. 80
Calibrator, Piezoelectric 343
Camera, Moving-film 54
Camera, Ortho-stereo and Stereoscope 312
Capacitance and Conductivity Bridge, Shielded.. 274
Carbon Monoxide Alarm 83
Cathode-ray Apparatus Terms 115
Cathode-ray Equipment 27
Cathode-ray Tubes, Electrode Arrangements for.. 266
Cathode-ray Tubes, Electrostatic Deflection Methods for 213, 225
Cathode-ray Tubes, Fluorescent Screens for 335
Cathode-ray Tube Focusing Arrangements 298
Centralizing Information on Special Research Instruments and Apparatus 119
Circuit Breaker, 125-Volt 315
Circuit Breaker, Small Oil Blast 248
Circuit Breakers, Lighting and Power Circuits... 344
Circuit Tester 279
Cloud & Pour Test Apparatus, A.S.T.M. 51
Color Comparator 277
Color Comparator and Reflector, Diffuse Illumination 82
Color Comparator, Photoelectric 218
Colorimeter, Photocell 137
Colorimeter, Photoelectric 218
Color Matcher, Photoelectric 218
Combustion Analyzer, Internal-combustion Engine 345
Combustion Control at the World's Largest Distillery, Automatic 252
Condensers, Mica, Laboratory 134
Condensers, Motor 27
Contactors, A-c. Magnetic 345
Contactors, Magnetic 315
Contactor, Magnetic Multipole 344
Contactors, Mill-type D-c. 344
Contour Measuring Projector 274
Control, Automatic Speed for Flexible-shaft Tool. 340
Control, Gas-air Ratio 221
Control of Pumps, Automatic 318
Control, Tank Discharge 342
Control, Temperature, Contactless Systems 304
Control, Temperature, for Internal Combustion Engines 220
Control Systems 272
Control System, Combination 52
Control System, Dual 137
Control Unit, Temperature 310
Controller, Adjustable-sequence Repeat 190
Controller for Machine Tools, Electro-hydraulic.. 220
Controller, "Fulscope" Time Schedule 106
Controller, Self Balancing 190
Controller, Sequence-repeat 138
Controller, Temperature 220
Controller, Temperature, with Built-in Relay 221
Controllers, Air-operated 220, 245, 311
Controller, Automatic 310
Controller, Automatic Pressure-time Cycle 137
Controllers, Draft 311
Controllers, Duct Pattern Humidity & Temperature 109
Controllers, Low-pressure or Draft 133
Controllers, Processing 221
Controllers, Temperature, Air-operated 304
Core Material, Metallic 272
Counters, High-speed 247
Creep of Metals, Measurement of 128
Crystal Oscillator 81
Current-testing Set 191
Daylight Lamp 136
Ded-Fuse Tattelites 222
Demand Meters 143
Demand Register Checking Device, Portable 309
Demand Register, Maximum 309
Dial Gage Mounting 51
Dial Indicator 246
Diffraction Analysis Apparatus 162
Drafting Machine, Portable 342
Dynamic Balancing Equipment 138
Dynamometers, High Speed 193
Dynamometer, Water 83
Electrical Indicating Instruments, Factor of Merit for Horizontal-shaft 112
Electrical Instruments, Edgewise Indicating 104
Electrical Instruments, Miniature 50
Electrical Instruments, Portable, Multi-purpose.. 308
Electrical Instruments, Small Square 340
Electrical Test Cart for Industrial Plants 212
Electricity Meters 62, 89
Electricity Meters for Special Rate Structures.... 178
Electrodialysis Apparatus 54
Electromagnetic Deflection Methods for Cathode-ray Tubes 242
Engine Indicator, Direct Pressure Type 83
Exposure Meter 312
Exposure Meter, Photoelectric 218
Eyepiece, Grain Size Measuring 312
Fatigue Tester, Torsional 28
Flow Controllers, Proportioners, etc. 107
Flow Meter 191
Flowmeter, Combination Feed Water 82
Flowmeter, Compressed Air 23
Flowmeter, Fuel and Air, for Furnaces & Kilns. 135
Flowmeter, Gas 23
Flowmeters, Improved Case for 22
Flowmeters, Liquid Fuel 22
Flowmeter using Null Method, Electric 25
Flowmeters, Re-designed 134
Flow of Fluids in Pipes 1
Flow-rate Indicator 281
Fluid Meter, Universal 59
Folding Tester, Paper 221
Furnace Temperature and Heating-rate Control by Dilating Wire 174
Gage, Rain and Snow 309
Gage, 2" Throat Pocket 106
Gage, Visual 163
Gaging Aids, Production 307
Galvanometer, Micro Oscillograph 26
Gas and Gasoline Analysis, Test Car Column for. 136
Gas Pressure Regulator 274
Hardness Testing Machine with Microscope 51
Hot Water Meters 82
Hot-wire Anemometer 80
Hydrogen-Ion Meter, Electrometer-tube Type 138
Hydrometers, Special-purpose 53
Hygro-thermograph 273
Illumination Analyzer 275
Illuminator for Microscopes, Surface 313
Impact Tester, Universal 278
Indicator, Load 306
Indicator, Phase-rotation 308
Induction Regulator for Small-capacity Circuits.. 165
Instrument Parts and Accessories, Electrical 51
Instrument Scale Distribution and Its Effect on Observational Errors 58
Instruments Contribute to Better Brake Performance 140
Instruments Used to Improve Automotive Riding Comfort 289
Insulation Purposes, Inspection of Textiles Used for Electrical 333
Interference Analyzer 248
Isometric Ruled Paper 54
Kva Meter, Recording 160
Laminated Contacts 109
Lightning, Electric Distribution Networks Improved by Instruments for Study of 270
Liquid Level "Stabilog" 190
Lubricating Oil, Effect of Carbon Suspensions on Some Properties of 170
Magnifier, Inspection 248
Magnifier, Self-illuminating 53
Materials Testing Machines 76, 130, 156
Mechanical Tests on Turbine Blades 154
Meter, Air, Dual-purpose 305
Meter, Capacity 308
Meter, Photoelectric Reflection 279
Meter, 2-Element, Detachable 309
Meter, Visibility 305
Metering for Special Rate Structures 120
Metering Pump, Oil 306
Microcinematography 168
Micrometer, Dial 247
Microphone, Crystal 84
Micro-projector 83
Microscope, Centrifuge 142
Microscope, Inspection 276
Millisecond Indicator 312
Moisture Meter 53
Mountings, Anti-vibration 308
Multipliers, Kilovoltmeter 192
Multi-range Laboratory Instrument, Self-checking 217
Oil Aging Tester 163
Orifice, Automatic Adjustable 245
Orifice Coefficients for Viscous Liquids ... 202, 225, 232
Orifice Fittings 193
Orsats, Air Bell for 247
Orsats, Vision Panel for 273
Oscillator, Beat Frequency 105
Oscillator, R-f. and A-f. 280
Oscillograph and Its Applications, Cathode-ray.. 186
Oscillograph, Cathode-ray 307
Oscillograph, Portable Cathode-ray 135
Oscillograph, Some Applications of Cathode-ray.. 32
Oscillograph, Universal 160
Oscillography, Widening Field of 186
Panel, Cabinet Type 109
Paper Testing Instruments 164
Permeameter, Full-range 342
Phantom Loads, Electric 280
Phase Rotation Checking in Reactive Metering ... 98
Photocell, High Output 308
Photoelectric Cell 218, 272
Photoelectric Control of Paper-roll Register 219
Photoelectric Instruments Count Vehicles Crossing Cairo (Ill.) Toll Bridge 254
Photoelectric Reflection Meter 279
Photo-optical Bench 81
Pliability Comparator 277
Polariscope, Inspection 276
Polisher, Specimen 340
Position Transmitter and Recorder 104
Positioner for Control Valves, Positive-action 314
Potentiometer, High-speed Automatic 343
Potentiometer, Portable 21
Pressure Control System 55
Pressure Control System, Furnace 21
Pressure, Draft and Differential Recorders 136
Pressure Gage, Absolute 343
Pressure Recorder, Absolute 26
Pressure Recorder, Piston Type Differential 281
Program Controller, 24-hour 220
Psychrometer, Aspiration 222
Psychrometer with Motor-driven Fan 81
Pyrometer, Control 26
Pyrometer Drive, Control 247
Pyrometer, Indicating 28
Pyrometers, Lance Form 53
Pyrometer, Needle 28
Pyrometer, Optical, Automatic 271
Pyrometer, Potentiometer 271
Pyrometers, Surface 161, 279
Pyrometer Indicator, Multi-circuit 219
Radium Detector, Portable 24
Range Multiplier for Light Meter 82
Rate Tester, Timepiece 307
Reactive Metering, Checking for Phase Rotation in 98
Recloser, Automatic 314
Recorder, Differential Pressure 223
Recorder, Multiple Pen 24, 216
Recorder, Steel Temperature 309
Recorder, Stock Market 54
Recording Electrical Instruments, Relay Type 7, 34
Rectifier 315
Regulator, Air Velocity 341
Regulators, Generator Voltage 84
Regulator, Paint Flow 248
Relays, Auxiliary 135
Relay, Illumination Control 108
Relay, Photoelectric 27
Relay, Photoelectric for Outdoor Lighting Control 345
Relay, Phototube 108
Relay, Selective 105
Relay, Sensitive 275
Relay, Synchronizing 108
Relay, Timing 165
Relays Find Important Applications on Modern Aircraft 61
Relays for Copper Oxide Rectifiers 28
Repeated-stress Testing Machine, High Speed 54
Resistors, Carbon 192
Resistors, Crolite 53
Resistor, Insulated 109
Resistors, Speed-regulating 280
Reynolds Number 322
Reynolds Number, Alternative Forms of the 201
Reynolds Number Originated and How to Compute Its Value, How the 198, 205
Rheostats, Field 247
Rheostats, Tandem Co-axial 53
Rotameters 136
Rotameter Safety Head 107
Sand Testing Instruments 84, 161
Sand Strength Tester 281
Scale, Pocket Spring 344
Selecting & Training Plant Instrument Maintenance Men 285
Slide Rule, Circular 50
Slip or Differential-Speed Indicator 206
Sound Level Indicator 275
Sound System Testing Apparatus 105
Spectrogram Comparator 280
Spectrometer and Monochromator, Universal Quartz 276
Spectrophotometer Assemblies 162
Steam Trap, Thermostatic 107
Stiffness Tester 22
Stirrer, Laboratory 249
Stress-strain Recorder for Testing Machines 81
Supervisory System 133
Switches, Combination Fan and Limit 55
Switch, Electronic C-R-O 345
Switch, Gas Safety 192
Switch, Mercury Tube Toggle 345
Switch, Motor Starting 28
Switch, Single-hole-mounting 23
Switch, Vacuum Power 223
Synchronizing Device 273
Synchronizing, New Method of Automatic 88
Tachometer, Electric 217
Tachometer, Stroboscope 246
Tank Gage, Magnetic 160
Telemetering and Totalizing 207, 235, 256, 293, 323
Telemetering System 23
Telephone Cords, Proofing Ground for 46
Temperature Indicator, Machine 217
Temperature Regulator, Electro-hydraulic 24
Tensile Tester, Universal 278
Tester, Cadmium & Zinc Coating 193
Test Equipment, Motor 313
Testing Machines, Materials 18, 48, 99
Thermocouple Head 192
Thermometers, Pasteurizer 193
Thermostat, Differential 28

Thermostats, "Summer-winter" Type 104
Thickness Gage, Electric 341
Thread Contactor, Vehicle 315
Time Controllers 278
Time Meter, Hour-register 275
Time Study, A Direct-record, Method of 320
Time Switches, 24-hour 341
Timer, Automatic Repeat 51, 311, 342
Timer, Spot Welding 28
Timer, Thermal Load 249
Torsion Impact Tester 80
Transformers, Precision 109
Transformer, 230-Volt "Variacs" 134
Transmitter, Aircraft 109
Tube Tester, Thermionic 223
Unbalance, Rapid Method for Determining and Correcting 228
Vacuum Gaging in Lamp Manufacture 262
Vacuum Regulator, Static Pressure or 340
Valves, Color Indexed 160
Valves, Control 193
Valve, "Flocontrol" 164
Valve Position Indicator 52
Valve, Relief, Flat Characteristic 310
Valve, Solenoid 22
Vapor-pressure Gage 80
Vapor-pressure Recorder 134
Vibrograph, Tri-dimensional 313
Viscometer, Enamelists' 161
Viscometer, Fitz-Simons 273
Voltage Regulators 109, 163, 277
Volt-hour Meter 108
Voltmeter, Contact-making 222
Voltmeters, Electrostatic 82
Volt-ohm-milliammeter in Kit Form 106
Water Gage, Precision 279
Water Level Control and Cut-off, Boiler 133
Water Level Indicator, Boiler 82
Watthour Meter Calculator 248
Watthour Meters for Current Transformer Errors, Adjusting 16
Wattmeter, Polyphase 161
Weigher, Automatic for Packaging Powders, etc. 344
Weigher-printer, Computing Moisture-content 344
Welding-time Recorder 281
Wheatstone Bridge 223
Wire Gage Recorder 192
X-Ray Diffraction Progress, Recent 302
X-Ray Equipment 306
X-Ray Equipment, Mobile 342
X-Ray Shield 107

AUTHOR INDEX

Accurate Instrument Co., Inc. 272
Acme Elec. & Mfg. Co. 277
Aerovox Corp. 27
Akatos, Inc. 82
Allen Elec. & Equip. Co. 313, 345
Allis-Chalmers Mfg. Co. 273
American Instrument Co. 24, 54, 218, 275
American Mach. & Metals, Inc., Riehle Test. Mach. Div. 278
American Meter Co. 22
American Transformer Co. 109
Ames Co., B. C. 51, 106, 247
Amthor Testing Inst. Co. 221, 278
Automatic Electric Co. 246
Automatic Temp. Control Co. 190, 342
Bacharach Ind. Inst. Co. 281, 309
Bailey Meter Co. 82, 109, 135, 245
Baker-Raulang Co. 242
Baldwin Southwark Corp. 80, 81
Barbour, William 212
Batcher, Ralph R. 115, 187, 213, 242, 266, 298, 335
Bausch & Lomb Optical Co. 83, 274, 312, 313
Behar, M. F. 7, 34, 62, 89, 120, 143, 178, 207, 235, 256, 293, 323
Biggs, W. F. 252
Binks Mfg. Co. 248
Black & Decker Co. 306
Blume, W. A. 140
Borden, Perry A. 7, 34, 62, 89, 120, 143, 178, 207, 235, 256, 293, 323
Bosomworth,, G. F. 285
Brevoort, Maurice J. 5
Bristol Co. 23, 26, 191, 271
Brombacher, W. G. 86
Brooke Engineering Co. 52
Brooks, J. A. 116
Brown Instrument Co. 21, 245
Brown, R. W. 289
Buckingham, Edgar 225
Buffalo Meter Co. 82
Burt Scientific Lab., R. C. 279
Cambridge Inst. Co. 28, 138
Carson, W. H. 204
Cash Co., A. W. 272
Chemical Publishing Co. 249, 280
Clough-Brengle Co. 27
Cochrane Corp. 25
Commercial Engineering Labs. 83
Consolidated Ashcroft Hancock Co. 164, 193, 220, 221
Continental Electric Co. 223
Crowley & Co., Henry L. 53, 272
Davis, Evan A. 128
Davis, E. C. 174
Delmonte, Jack 61
Detroit Lubricator Co. 22, 28, 55
Detroit Test. Mach. Co. 52, 306
Dietert Co., Harry W. 84, 161, 281
Drafto Co., The 342
Dudley, A. M. 30
DuMont Lab., Allen B. 307, 345
Dumore Co. 340
Durant Mfg. Co. 247
Eby, Inc., Hugh H. 218
Eclipse Aviation Corp. 22
Eddy, C. T. 174
Edison, Inc., Thomas A. 165, 220, 310
Electric Con. & Mfg. Co. 51, 315, 345
Electric Storage Battery Co. 108
Electrical Research Products, Inc. 105, 275
Electronic Products Co. 27
Elgin Softener Corp. 134
Ellison Draft Gage Co. 247, 273
Erie Resistor Corp. 109
Esterline-Angus Co. 160
Evans, H. J. 204
Exact Weight Scale Co. 344
Fassin, Gustave 142
Federal Products Corp. 192, 246, 307
Ferranti Electric, Inc. 82
Fielder, F. D. 32
Fisher Governor Co. 137
Ford, Adelbert 320
Foster Engineering Co. 220
Foxboro Co. 50, 80, 190, 193, 247, 343
Frank, K. G. 53, 248
Friez & Sons, Inc., Julien P. 104, 109, 273, 305, 309
R. Fuess, Inc. 80, 81, 164
Gaertner Scientific Corp. 162, 276, 280
Gamewell Co. 105
General Electric Co. 23, 28, 84, 108, 109, 133, 138, 163, 191, 193, 217, 222, 248, 280, 281, 305, 308, 312, 315, 341, 342, 344, 345
General Plate Co. 109
General Radio Co. 54, 134, 246, 277
Gibbons, C. H. 18, 48, 76, 99, 130, 156
Gordon Co., Claud S. 192
Graybill, K. W. 46
Green, Howard R. 318
Gurley, W. & L. E. 22
Hart Mfg. Co. 345
Hays Corp. 136
Hays Laboratories 218
Heiland Research Corp. 26
Hickok Elec. Inst. Co. 104, 280
Hodgson, John L. 322
Holland, W. A. 88
Holz, Herman H. 28, 163
Hommel Co., O. 161
Hoyt Elec. Inst. Works 340
Ideal Commutator Dresser Co. 217
Illinois Testing Labs., Inc. 191, 219, 343
Industrial Engineers, Inc. 134
Isenburger, Herbert R. 302
Jenkins Bros. 160
Jewell, R. G. 58
Johnson Service Co. 81
Keith, Rafael W. 198
Klipfel Mfg. Co. 310
Kroon, R. P. 154
Krouse, Glen N. 54
Leeds & Northrup Co. 21, 24, 83, 190, 274
Leitz, Inc., E. 340
Leonard Elec. Mfg. Co. 279
Lightning Calculator Co. 80
Littelfuse Labs. 222
Lockwood, L. D. 262
Loewenberg, F. 272
Lucke, C. E. 205
MacGahen, Paul 186
McAlear Mfg. Co. 274
McDonnell & Miller 133
Miles Reproducer Co. 108
Milligan & Wright Co. 52, 249
Mine Safety Appliance Co. 83
Minneapolis-Honeywell Regulator Co. 82, 133, 271
Morey & Jones, Ltd. 223
M-R-H Labs. 137
Muter Co. 223
New Jersey Meter Co. 23
Niles Reproducer Co. 108
Ohio Carbon Co. 192
Ohmite Mfg. Co. 53
Palmer Co. 222
Partlow Corp. 221
Paulson & Co., Henry 307
Pfaltz & Bauer, Inc. 279
Philadelphia Drying Machinery Co 221
Pittsburgh Equitable Meter Co. 28
Pittsburgh Inst. & Mach. Co. 51
Plating Products Co. 193
Powers Regulator Co. 304, 340, 341
Proportioneers, Inc. 342
Pyrometer Instrument Co. 161
Rah & Co., Joseph C. 107
RCA Mfg. Co. 135, 343
RCA Victor Co. 105
Refining Supply Co. 136
Remler Co. 104
Rhamstine, J. Thos. 312, 315
Richardson, H. W. 16
Rimbach, Richard 119
Rinfield Electrical Inst. Corp. 217
Rochester Mfg. Co. 160
Roger, Henry 168
Roller-Smith Co. 161
Ruggles-Klingemann Mfg. Co. 310
Rushing, F. C. 228
Russell Elec. Co. 53
Ruths Steam Storage Co. 55
St. John X-Ray Service, Inc. 162, 306
Sangamo Elec. Co. 309
Sarco Co. 107
Schilling, E. W. 206
Schutte & Koerting Co. 107, 136, 281
Schweitzer & Conrad, Inc. 279
Shallcross Controls, Inc. 311
Shallcross Mfg. Co. 192
Sheffield Gage Corp. 163
Smith, Alexander 270
Smith, Jr., Ed S. 201, 202
Smith, H. Hunter 170
Smith, Ronald B. 204
Smith-Taber Co. 277
Smith & Winchester Mfg. Co. 219
Spencer Thermostat Co. 192
Sprague Products Co. 248
Sprenkle, R. E. 232
States, C. 280
Steel Co., Herman D. 248
Stickney, F. S. 112
Stromberg Motoscope Corp. 53
Tagliabue Mfg. Co., C. J. 51, 134, 136, 193, 311
Tavella Sales Co. 50
Taylor Instrument Co.'s 106, 137, 138, 314
Tech Labs. 343
Technigraph, Inc. 54
Tefft-Jackson, Inc. 52
Thayer, Charles H. 98
Thermo Control Devices, Inc. 304
Thomander, Vernon S. 186
Thwing Instrument Co. 28
Toledo Scale Co. 344
Tork Clock Co., Inc. 220
Torque Products Co. 83
Triplett Elec. Inst. Co. 106
Trub, Tauber & Co. 53
Turner Co. 84
Tuve, G. L. 232
Van der Pyl, Lyman M. 1
Van Laethem, J. 333
Vermimmen, R. 333
Vibration Eliminator Co. 308
Vibration Specialty Co. 313
Vickers, Inc. 220
Vigelius, F. W. 174
Wade Instrument Co. 54
Walser Automatic Timer Co. 249, 278
Ward Leonard Elec. Co. 247, 315
Wenz, Russell C. 254
Westinghouse Elec. & Mfg. Co. 50, 81, 82, 104, 109, 135, 160, 165, 219, 275, 308, 309, 311, 314, 344
Weston Elec. Inst. Corp. 51, 108, 218, 223, 305, 308, 343
Wicaco Mach. Corp. 306
Wilbin Inst. Co. 24
Wilkins-Anderson Co. 108
Williamson, H. 206
Zenith Elec. Co. 311

BOOK REVIEWS

SUBJECT INDEX

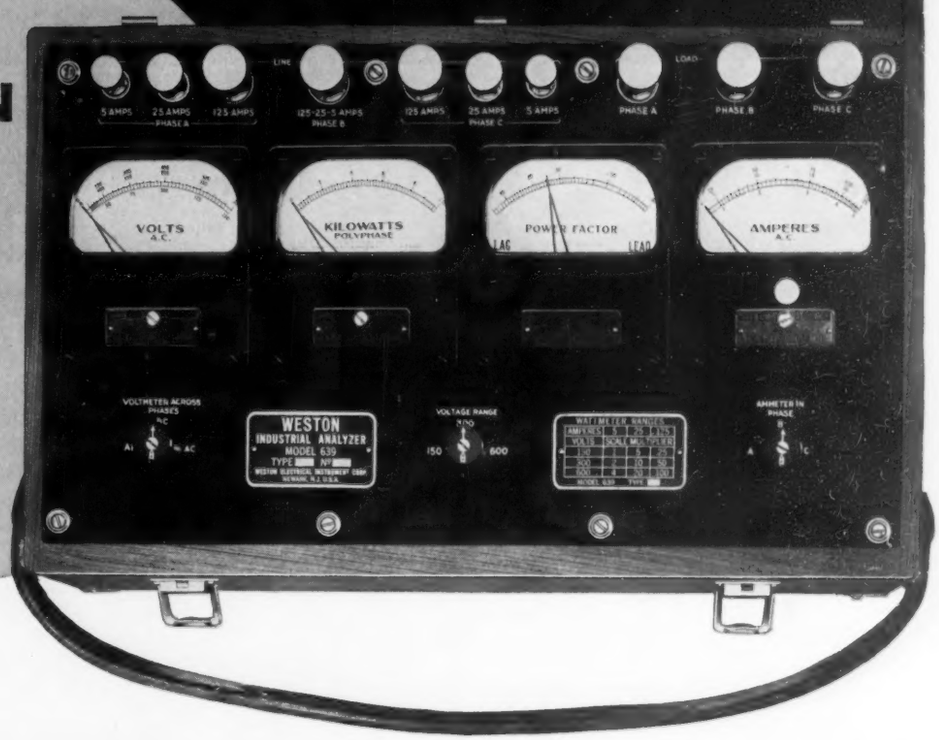
Applied Acoustics 51
Automatic Protection of A-c. Circuits 73
Dictionary for Photogrammetry 14
Electric Power Metering 71
Electron Tubes in Industry 33
Flow of Water in Pipes, Sewers and Channels; over Weirs, and off Catchments 135
Foremanship Development 234
Hardness of Metals and Its Measurement 50
Heat 234
Marketing Industrial Equipment 234
Objektive Photometrie 278
Practice of Absorption Spectrophotometry with Hilger Instruments 14
Photoelectric and Selenium Cells 234
Scales in the Course of Time 135
Symposium on Illumination 276
Technical-Physical Practice 278
Telemetering 152
Television, Theory and Practice 33
Trouble-Shooting for Radio Service Men 14

AUTHOR INDEX

Allsopp, C. B. 14
Cork, James M. 234
Deutsche Gesellschaft fur Photogrammetrie 14
Fielding, T. J. 234
Freed, B. M. 14
Gheradi, A. A. 14
Grieveson, C. J. W. 276
Henney, Keith 33
Industrial Relations Department, Westinghouse Elec. & Mfg. Co. 234
Knoblauch, Osc. and Kock, We. 278
Knowlton, Archer E. 71
Kouhm, August 135
Lester, Bernard 234
Massa, Frank 51
Olson, H. F. 51
O'Neill, Hugh 50
Reyner, J. H. 33
Sewig, Rudolph 278
Stablein, W. 152
Stubbings, O. W. 73
Twyman, F. 14
Williams, George Bransby 135

Now ONE INSTRUMENT TO CONNECT INSTEAD OF FOUR

THE **WESTON** INDUSTRIAL POWER ANALYZER



has ALL INTERCONNECTIONS MADE—MAKES TESTING QUICK AND SIMPLE

RANGE SCOPE

150 — 300 — 600 volts

•

5 — 25 — 125 Amperes

•

30% lag to 80% lead 3 phase power factor

•

Kilowatts up to 100

•

Weight 32 lbs.

To appreciate the ease and speed of load testing with the new Weston Industrial Analyzer, just follow the few steps necessary in obtaining, for example, the full characteristics of a 3 phase load. Here they are:

Connect the three line leads and the three load leads . . . just one hook-up. Use the selector switch at the left to obtain voltage readings across any pair of the three lines. The switch at the right connects the ammeter to read current in any phase. That's all there is to it.

Contrast this with the amount of equipment and the lengthy procedure involved where individual instruments are used. Instead of a number of instruments, plus multipliers, plus transformers, you have a compact kit, already hooked up, for quick and complete analysis of industrial loads.

The Model 639 Weston Industrial Analyzer measures current, voltage and power in single or polyphase circuits and power factor in 3 phase circuits. In addition, provision is made for measuring transients such as starting current of induction motors. A bulletin is available giving complete data. Write for your copy today . . . Weston Electrical Instrument Corporation, 591 Frelinghuysen Avenue, Newark, New Jersey.

NRA

WESTON *Instruments*

INSTRUMENTS

THE MAGAZINE of MEASUREMENT and CONTROL

RICHARD RIMBACH
Managing Editor

M. F. BEHAR
Editor

Editorial Advisory Board

G. BERNDT
Technische Hochschule, Dresden

W. G. BROMBACHER
National Bureau of Standards

A. V. DeFOREST
Massachusetts Inst. of Technology

K. J. DeJUHASZ
Pennsylvania State College

PAUL B. FINDLEY
Bell Telephone Laboratories

JOHN L. HAUGHTON
National Physical Laboratory, England

H. L. HAZELTINE
Sterling Varnish Company

C. A. HEILAND
Colorado School of Mines

GEORGE KEINATH
Editor, Archiv fuer Technisches Messen

E. S. LINCOLN
Consulting Electrical Engineer

JOSEPH LYNCH, S.J.
Seismic Station, Fordham University

FOSTER D. SNELL
Consulting Chemist

THOMAS SPOONER
Westinghouse Elec. & Mfg. Co.

S. R. WILLIAMS
Amherst College

Published Monthly on the 15th by
The Instruments Publishing Company
1117 Wolfendale Street
Pittsburgh, Pa.
JOSEPH J. VIGNEAU, President
RICHARD RIMBACH, Vice-Pres.-Treas.

Branch Offices
Boston: James Condon, 6 Marlboro St.
New York: Edwin F. Ripley, 118 E. 28th St.

Annual Subscription: U. S. $2.00. All other countries $3.00 (Remit by New York Draft).
Copyright 1935 by The Instruments Publishing Company.
Entered as second-class matter January 26, 1932, at the post office at Pittsburgh, Pa., under the Act of March 3, 1879.

CONTENTS · JANUARY 1935

Cover: American Boiler Control Panel at a French Station

The Flow of Fluids in Pipes 1
By Lyman M. Van der Pyl

"Instrumentation Terms" 4
Further Discussion of *Instruments'* Editorial—
By H. H. Sticht

An Air-damped Accelerometer 5
By M. J. Brevoort

Electrical-relay Type Recording Instruments . . 7
By Perry A. Borden and M. F. Behar

INSPECTION AND TESTING

Adjusting Watthour Meters for Current Transformer Errors 16
By H. W. Richardson

Materials Testing Machines—Part Three . . . 18
By C. H. Gibbons

NEW INSTRUMENTS

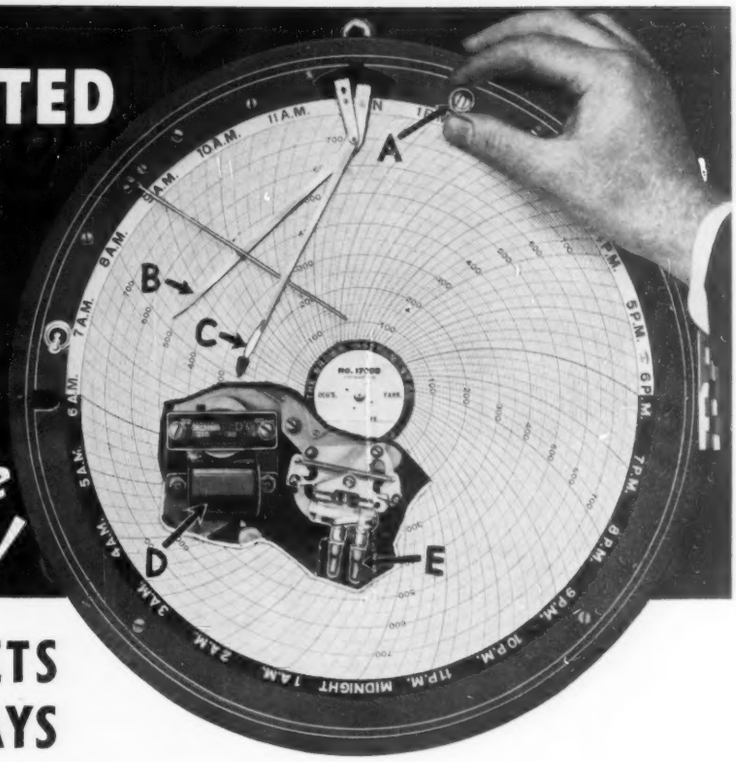
Portable Potentiométer 21
Furnace Pressure Control System 21
R. D. Stiffness Tester 22
Improved Case for Flowmeters, etc 22
Liquid Fuel Flowmeters 22
Solenoid Valve 22
Compressed Air Flowmeter 23
Gas Flowmeter 23
Re-designed "Metameter" Telemetering System 23
Single-hole-mounting Switch 23
Electro-hydraulic Temperature Regulator 24
"Numerals in Colors" for Multiple-point Recording 24
Portable Radium Detector 24
Electric Flowmeter Using Null Method 25
Control Pyrometer 26
Absolute Pressure Recorder 26
Micro Oscillograph-Galvanometer 26
Photoelectric Relay 27
Cathode-ray Equipment 27
Motor Condensers 27
Needle Pyrometer 28
Spot Welding Timer 28
Torsional Fatigue Tester 28
Motor Starting Switch 28
Indicating Pyrometer 28
Differential Thermostat 28
Relays for Copper-oxide Rectifiers 28

Editorial Comment A4
Instruments' Book Shelf 14
Instruments Index A5
Advertisers' Index A6
Manufacturers' New Literature 24

INDEX TO VOLUME SEVEN (1934) IN BACK OF THIS ISSUE

MOTOR-OPERATED MERCURY SWITCHES

...Assure Positive Control Action!



NO EXPOSED CONTACTS .....NO RELAYS

The Brown Thermometer Controller enables you to hold your processes within closer temperature limits. The use of mercury switches in the design of circular chart controllers is a revolutionary development that overcomes the limitations caused by the antique method of open "make and break" contacts. Only in the new Brown Thermometer Controller will you find this modern advancement built to meet industrial conditions as they exist today or will tomorrow.

Highly responsive bulb system and unhampered pen movement is practically instantaneous in recording temperature changes.

Every six seconds the motor-operated mechanism determines the location of the pen in reference to the control setting, and operates the mercury switches as required. It is so designed that it does not interfere with the measuring system, as the mercury switches are motor-operated.

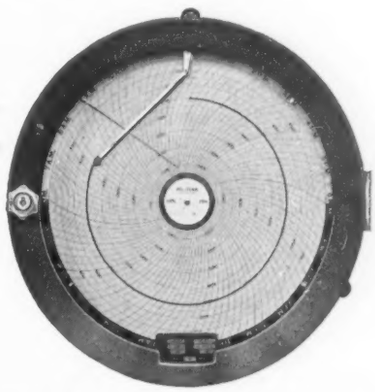
The Brown Thermometer Controller combines accuracy with ruggedness. You will welcome its assistance—you can rely on its accuracy—be confident of its dependability. Write for catalog No. 6702.

THE BROWN INSTRUMENT COMPANY
4482 Wayne Ave. Philadelphia, Pa.
Branches in 22 Principal Cities

NRA MEMBER U.S. WE DO OUR PART

CONTROLS AND RECORDS TEMPERATURES
up to 1200° F.

(A) Knob for changing setting of B: (B) Index showing temperature at which Indicating Control is set: (C) Temperature Pen: (D) Electric motor selects switch position depending upon relation of C to B: (E) Mercury in glass switches, capacity 15 amperes at 110 volts, positive in action, are mechanically positioned by Motor D.



RECORDING CONTROLLERS
Priced as low as **$97.00**

BROWN THERMOMETER CONTROLLER

"to measure is to economize"

EDITORIAL COMMENT

In This Issue

All readers who use fluid meters—that is to say a large majority of our subscribers—will thank L. M. Van der Pyl for his painstaking and judicious correlation of recent authoritative data on pipe flow. His article this month is the second of a series he is preparing for *Instruments*, each on one particular subdivision of Instrumentation.

The second article contains more information—and of more general interest—than is suggested by the modest title "An Air-damped Accelerometer." M. J. Brevoort's appendix on the principles of accelerometer performance constitutes in itself a fine discussion of damping characteristics applicable to many different types of instruments.

This month's instalment of our electrical measurements series continues the treatment of recording electrical instruments, and deals only with electrical-relay or contact-type recorders.

Next comes our new department, *Inspection and Testing*, as announced in the adjoining column. The first article in it is a much-needed detailed exposition of all steps to be taken in adjusting watt-hour meters for current transformer errors. H. W. Richardson takes up only the single-phase meter (the polyphase would require a book for a similar detailed procedure) and in order to exaggerate errors he assumes the meter to be connected to a bushing type transformer. We recommend instrument transformers for all measurement or metering applications.

C. H. Gibbons continues his fascinating story of testing machines and brings us nearer to the modern forms, his first illustration this month showing a type which is still in use in Germany.

Did you ever listen on the radio to "the tune detective" who points out how the same theme was used by Beethoven, then in a waltz, a march, a rollicking ballad and a "blues" number? Under *New Instruments* this month you will see the identical "theme" (the area-meter principle) used by three different manufacturers who have independently brought out new flow indicators for liquids, for compressed-air and for low-pressure gases.

The Front Cover

"The French they are a clever race." They have made important contributions in many fields of measurements, notably in bringing out the first practical pyrometers. They are the first to admire foreign developments, and are not too proud to adopt them, as witness this month's cover photograph which shows one of the boiler control panels of the St. Denis Station of the Société Electricité de Paris—built in Cleveland, Ohio, U.S.A., by the Bailey Meter Co.

Instrumentation's New Frontier

IT will be noticed that page 15 of this issue echoes the front cover of *Instruments* in such a manner as to convey the impression of "a magazine within a magazine," named *Inspection and Testing*. This implies no change of editorial policy. *Instruments* will continue to give you a balanced diet on all branches of Instrumentation. In each issue from now on, however, articles bearing on inspection and testing methods and instruments will be run in a separate department with a pictorial title page.

Cause and effect are both involved in this departmentization. In one sense we are obeying the mandate of industry which shows an enormously increased demand for inspection robots and for improved testing machines (and for articles on such instruments); in another sense *Instruments* is the cause of this intensified demand.

At the risk of seeming immodest, we claim for *Instruments* the credit of stimulating industry to discard manual and visual inspections in favor of instrumental methods wherein human judgment is eliminated. In support of this claim we present our 1934 issues. Not that we had overlooked modernized inspection before that—on the contrary, *Instruments* had led this movement since 1928—but it was just a year ago on this very page that we solemnly declared our intention of *deliberately* promoting the extension of Instrumentation into inspection operations.

Just what did *Instruments* do along this line in 1934? "Industry" being a broad term, we shall report but one fact, pertaining only to industries that make and use paper products. Here is the fact: During 1934 *Instruments* printed a greater number of illustrated technical descriptions of instruments for inspecting and testing paper products than did all the periodicals serving the industries which produce and utilize these products.

Enough said about *Instruments'* part, which is essentially that of a catalyst, for the actual work of extending Instrumentation into new fields of inspection and testing is being achieved by you—the subscribers. Yours is the hard work of studying a multitude of individual problems and specifying the correct instruments.

It is more than work: it is a fight, for there is a strong sentiment against the introduction of such devices. At dinner in a politician's home recently, we mentioned seeing an inspection robot that tests wrist-pins for hardness, smoothness, cylindricality, concentricity, and diameter at the rate of 2200 per hour and places them into five classification bins—work that would otherwise require ten or twenty girls—whereupon he and his family joined in a chorus of anti-science and anti-industry tirades.

You probably have had similar experiences, dear reader, for your job is to cut down waste and eliminate drudgery. You know, of course, that the answer to attacks on instrumental inspections may be summed up in the word "civilization." In a land where the average man eats a few handfuls of rice a day and consumes a yard of cloth a year, everyone works—but everyone is underfed, ill-clothed, undeveloped mentally and spiritually.

So we repeat what we declared a year ago in launching our campaign for automatized inspection operations:

> We urge all industries now relying on manual and visual methods for inspections to install automatic instruments, thereby decreasing the sum total of human toil and increasing per capita leisure. Whatever device diminishes the sum total of drudgery is a blessing. Don't use fewer such devices, as some politicians advocate: use more of them! . . . We are all for the idea of equitably spreading both purchasing power and leisure, *but there must be more and more leisure to spread at the same time that more and more goods are produced and purchased.* We Americans can increase leisure by living like savages who don't travel, don't buy gadgets, don't read, write or 'phone and therefore have no industries; but to increase both leisure and industrial activity we must adopt more and more leisure-producing instruments and control devices.

A century ago the pioneers were fighting redskins to expand this nation's habitable territories. Instrumenticians today are the frontiersmen whose valiant efforts will enable industry to occupy the new territories of modern inspection and testing methods.

M. F. BEHAR

The Flow of Fluids in Pipes

By LYMAN M. VAN DER PYL*

SO IMPORTANT are the phases of modern industry represented by the movement of fluids through pipes that it is not surprising to find considerable energy being expended in studying the problems of pipe flow. Historically the subject begins with the ancients, though their contributions were not extensive since most of their conduits were open or, if closed, not flowing full. In the last two hundred years the work on the subject has consisted chiefly in fitting empirical formulas to experimental results; for instance, Lindquist[1] has reported 27 formulas that have been proposed, and Kemler[2] has listed 91 values put forth as constants for the friction factor in the so-called dimensional formula. Recently, however, various investigations have been concerned with the mechanism of flow.

One of the most important tools of the present-day hydraulician is the principle of hydraulic similarity, resulting from the work of Osborne Reynolds.[3] Briefly stated, similarity of two or more flowing conditions is attained when the value of the expression $\frac{vd}{\nu}$ is the same, provided that the roughness of the pipe wall in each case is proportional to the diameter. Thus, this expression, called the Reynolds number, serves as a means of correlating the data on different fluids in pipes of different sizes. Its validity has been confirmed by numerous investigators, among them Blasius[4], Stanton and Pannell[5], Parry[6], and Kemler[2]. Its applications will be brought up in the discussion to follow.

Poiseuille[7], nearly a hundred years ago, formulated the law of viscous flow; it is

$$\Delta P = \rho h = \frac{32 \mu l v}{g d^2} \quad . \quad . \quad (1)$$

The velocity profile is a parabola, expressed by the formula

$$u = \frac{\Delta P}{4 \mu l} (r^2 - a^2) \quad . \quad . \quad (2)$$

The maximum velocity occurs at the center of the pipe, when $a = 0$, and is twice the average velocity; the average velocity is found at $a = 0.707r$.

Viscous or streamline flow changes to turbulent flow at a critical velocity when the Reynolds number is between approximately 1200 and 2500; the exact value varies with the conditions, since the prevailing type of flow tends to continue into the range of the other type. As stated by Prandtl[8], viscous flow changes to turbulent flow when the velocity profile shows a point of inflection, which may be caused by such effects as a change in pressure or in the direction of flow; once started, the turbulence spreads rapidly and the instability of the changeover yields to the stability of steady turbulent or "dynamic streamline"[9] flow.

To correspond with the absolute viscosity of streamline flow, Stanton[10] and Smith[9, 11] have used the term "mechanical viscosity" to explain the phenomena of turbulent flow. While the absolute viscosity of viscous flow is due to the interchange of momentum on a molecular scale across a streamline, the analogous mechanical viscosity of turbulent flow results from the interchange of momentum on a macroscopic scale across a dynamic streamline in connection with the eddying of the fluid.

With turbulent flow in smooth pipes the velocity profile is essentially parabolic over the central four-fifths of the pipe diameter, as shown in Fig. 1[10], indicating that the mechanical viscosity is practically uniform in this range. The section of the curve near the pipe wall, with its more rapid change in velocity, shows that the mechanical viscosity decreases as the pipe walls are approached until, in the boundary layer at the pipe wall, the flow is purely viscous. With higher velocities, and so with higher Reynolds numbers, the increased momentum results in an increase in the mechanical viscosity; consequently the shoulder of the velocity profile moves out nearer to the pipe wall. In the case of rough pipes, we find that the mechanical viscosity is increased by the wall roughness and the velocity profile is parabolic practically to the pipe walls. The ratio of average to maximum velocity is variable with the Reynolds number, as shown in Fig. 2[12].

According to Prandtl's early experiments with turbulent flow, the velocity of flow near the wall of smooth pipes varies as the 1/7th power of the distance from the pipe wall[13], though it was later found that at high Reynolds numbers this exponent decreases to 1/10 and that in rough pipes it increases to 1/4. Prandtl, in his recent summary of the knowledge of turbulence[8], uses a dimensionless expression, $\frac{v_* y}{\nu}$, analogous with the Reynolds number, in a formula to express the velocity profile for turbulent flow in smooth pipes.

$$u = v_* \left(5.75 \log \frac{v_* y}{\nu} + 5.5\right), \quad . \quad . \quad (3)$$

applicable to conditions well into the pipe. The term v_*, called the shear stress velocity, is defined by the equation

$$v_* = \sqrt{\frac{\tau_0 g}{\rho}}, \quad . \quad . \quad . \quad (4)$$

in which τ_0, the shear stress between the fluid and the pipe wall, may be calculated from the equation

$$\tau_0 = \frac{r \rho h}{2 l} \quad . \quad . \quad . \quad . \quad (5)$$

Prandtl's plot of $\frac{u}{v_*}$ against $\frac{v_* y}{\nu}$ is shown in Fig. 3, along with a curve plotted from the formula

$$\frac{u}{v_*} = 8.7 \left(\frac{v_* y}{\nu}\right)^{1/7} \quad . \quad . \quad (6)$$

derived from Blasius' pipe friction formula. Prandtl's test points agree very well with his curve except at the lower end, where an effect of viscosity is supposed to interfere; however, the deviation affects only a very thin layer at the pipe wall, except for Reynolds numbers just above the critical point. The departure of the 1/7th power formula from the actual test data is shown very clearly.

Nikuradse has established a relation to express the velocity distribution for turbulent flow in rough pipe, as shown in Fig. 4[14], where it is presented as a plot of $\frac{v_{max} - u}{\sqrt{\frac{\tau_0 g}{\rho}}}$ against y/r. The agreement between the test points for both smooth and rough pipes is very good.

Turning now to the pressure loss encountered in pipe flow, we find an excellent summary of the data in a paper

*Pittsburgh Equitable Meter Co.

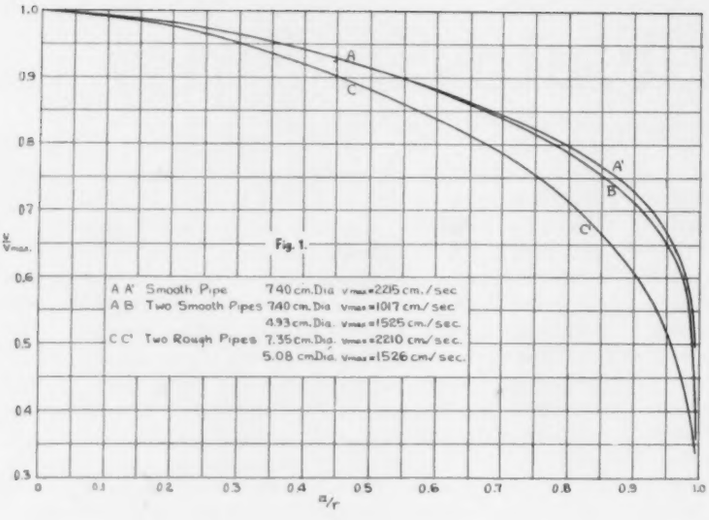


Fig. 1.
A A' Smooth Pipe 7.40 cm. Dia. vmax = 2215 cm./sec.
A B Two Smooth Pipes 7.40 cm. Dia. vmax = 1017 cm./sec.
4.93 cm. Dia. vmax = 1525 cm./sec.
C C' Two Rough Pipes 7.35 cm. Dia. vmax = 2210 cm./sec.
5.08 cm. Dia. vmax = 1526 cm./sec.

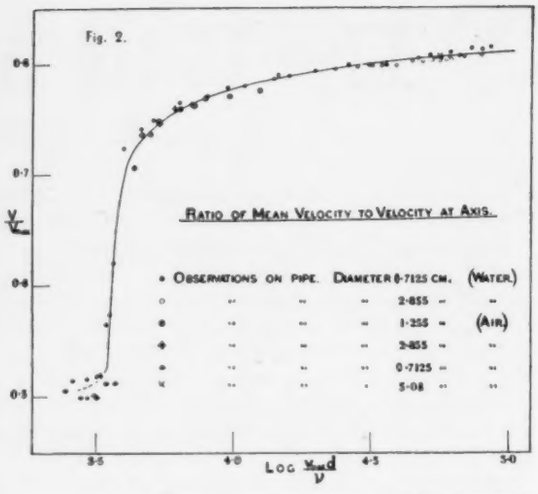


Fig. 2.
Ratio of Mean Velocity to Velocity at Axis.
Observations on pipe. Diameter 0·7125 cm. (Water)
2·855 cm. "
1·255 cm. (Air)
2·855 cm. "
0·7125 cm. "
5·08 cm. "

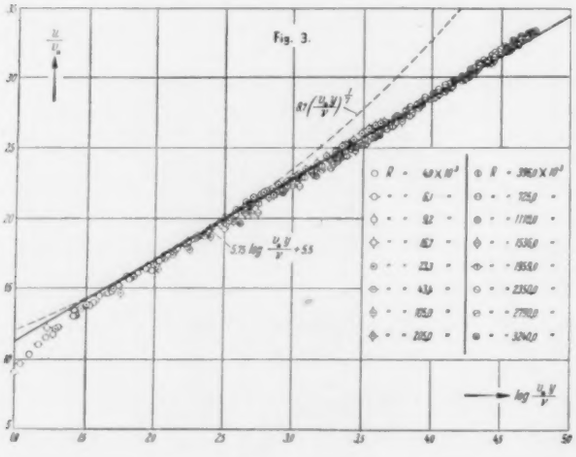


Fig. 1. Velocity Distribution with Turbulent Flow in Smooth and Rough Pipes

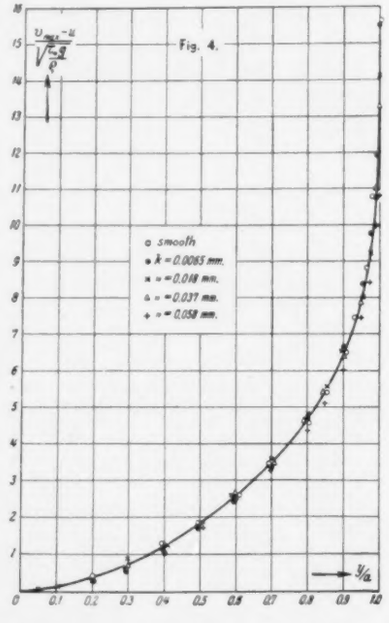
Fig. 2. Change of the Ratio of Average to Maximum Velocity with the Reynolds Number

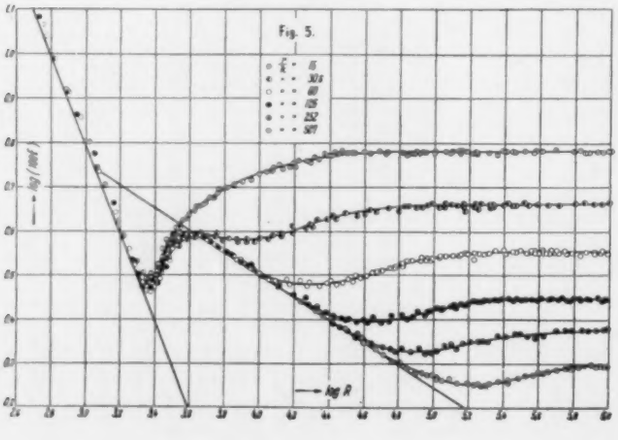
Fig. 3. Velocity Distribution with Turbulent Flow in Smooth Pipe

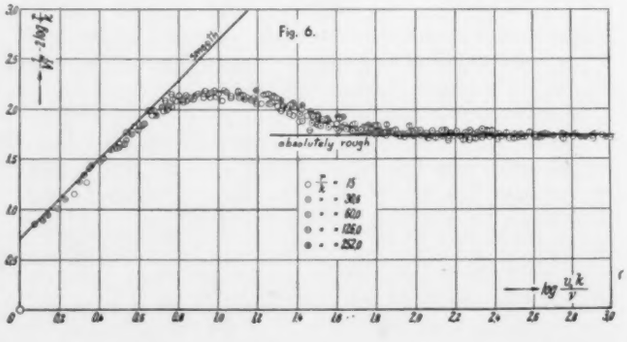
Fig. 4. Velocity Distribution with Turbulent Flow in Rough Pipe

Fig. 5. Friction Factor for Artificially Rough Pipe

Fig. 6. Roughness Function







by Kemler in terms of the friction factor of the dimensional formula

$$\Delta P = \rho h = \frac{f l v \rho}{2 g d} \quad . \quad . \quad (7)$$

or in the form applying to compressible fluids flowing under high pressure drops

$$P_1^2 - P_2^2 = \frac{f l v_2^2 \rho P_2}{g d} \quad . \quad . \quad (8)$$

Formula 7 goes under the names of both Darcy and Fanning, although it seems to have been originated by d'Aubisson de Voisins in 1834.[1]

Pigott[15] has correlated Kemler's summary and has given us the most comprehensive and convenient data so far presented on the pressure loss occurring in pipe flow. Fig. 7 shows his curves for the friction factor f. The curves numbered 1 to 10 were based on experimental data while the other curves were chosen arbitrarily to fill the range between curve 10 and the "entirely rough" curve 18. Each of these curves corresponds to a certain relative pipe wall roughness, the code being given in Table 1. The roughness in the table is given in terms of the percentage by which the friction factor of any conduit exceeds that of a perfectly smooth pipe. The figures

in the table are diameters of the conduits in inches, actual diameters being used for the drawn tubing, nominal sizes for the other pipes.

It will be noted that the friction factors are expressed as functions solely of the Reynolds number, the relation being

$$f = \frac{c_a}{\left(\frac{vd}{\nu}\right)^n}.$$

It is in this way that the characteristics of the flowing medium are introduced into the dimensional formula, and it is this feature that makes the dimensional formula the useful instrument it has proven itself to be in the work of the oil-pipe-line and chemical engineers. However, there are two other formulas used by large industries dealing extensively with flow in pipes—the Hazen-Williams formula used in water supply work and the Weymouth formula in gas transmission work.

The Hazen-Williams formula[16] is

$$v = C m^{0.63} s^{0.54} \times 0.001^{-0.04} \quad . \quad (9)$$

which may be reduced to

$$v = 0.550\, C\, d^{0.63} \left(\frac{h}{l}\right)^{0.54} \quad . \quad (10)$$

or, in the form of the dimensional equation,

$$h = \frac{3.02\, v^{1.852}\, l}{C^{1.852}\, d^{1.167}} \quad . \quad . \quad . \quad (11)$$

The term C is a factor that varies to account for the characteristics of the pipe wall, the values ranging from 140 for smooth new pipes to 100 or less for old tuberculated iron pipes. The curious factor $0.001^{-0.04}$ was introduced to make the values of C conform with those used with the earlier Chézy formula.

To find the friction factor of the Hazen-Williams formula we may equate formula (11) to the dimensional formula (7); substituting values for g and introducing the viscosity of water, the friction factor is found to be of the type

$$f = \frac{c_b}{\left(\frac{vd}{\nu}\right)^{.148} d^{.019}} \quad . \quad . \quad (12)$$

Thus the friction factor is not a pure function of the Reynolds number but includes in the denominator a small additional factor involving the pipe diameter. The effect of this additional factor is to reduce the friction factor for large pipes, which is a logical procedure, since the relative roughness of a given pipe surface decreases with pipe size. However, this small factor is by no means great enough to overcome the generally inaccurate assumption involving C that the relative pipe roughness is constant for all sizes of a given type of pipe. Also the constant exponent 0.148 of equation 9 means that the

TABLE 1—SELECTED LOCATION OF f BY ROUGHNESS RELATION FOR FIG. 7

Curve	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Roughness, %	0.2	0.45	0.81	1.35	2.1	3.0	3.8	4.8	6.0	7.2	10.5	14.5	19.0	24.0	28.0	31.5	34.0	37.5
A	0.35 up	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.125	.....	.....	.....	0.0625
B	72	48 to 66	14 to 42	6 to 12	4 to 5	2 to 3	1½	1 to 1¼	¾	½	⅜	¼	⅛	.....	.....	.....	.....	.....
C	.....	.....	30	10 to 24	6 to 8	3 to 5	2½	1½ to 2	1¼	1	¾	½	.....	⅜	.....	¼	.....	⅛
D	.....	.....	48 to 96	20 to 48	12 to 16	5 to 10	3 to 4	2 to 2½	1½	1¼	1	.....	.....	.....	.....	.....	.....	.....
E	.....	.....	96	42 to 96	24 to 36	10 to 20	6 to 8	4 to 5	3	.....	.....	.....	.....	.....	.....	.....	.....	.....
F	.....	.....	220	84 to 204	48 to 72	20 to 42	16 to 18	10 to 14	8	5	4	3	.....	.....	.....	.....	.....	.....

A = Drawn tubing, brass, tin, lead, glass.
B = Clean steel, wrought iron.
C = Clean, galvanized.
D = Best cast iron, cement, light riveted sheet ducts.
E = Average cast iron, rough-formed concrete.
F = First-class brick, heavy riveted, spiral riveted.

SYMBOLS USED IN THIS ARTICLE

a = distance from axis of pipe, ft.
c_a, c_b, c_c = constants.
C = pipe roughness factor of Hazen-Williams formula, no dimensions.
d = diameter, ft.
f = friction factor of the dimensional formula, no dimensions.
g = acceleration due to gravity, ft./sec.
G = specific gravity, referred to air = 1.0, dimensionless.
h = loss in head, ft. of fluid.
k = mean height of the irregularities of the walls of a pipe, ft.
l = length of conduit, ft.
L = length of conduit, miles.
m = mean hydraulic radius, ft., $= \frac{d}{4}$ for round pipes.
n = the coefficient determining the slope of the friction factor curves, no dimensions.
p = pressure, lb./in.²
P = pressure, lb./ft.²
p_o = absolute base pressure, lb./in.²
Q = flow, ft.³/hr. at T_0 and p_o.
r = radius, ft.
$R = \frac{vd}{\nu}$ = the Reynolds numbers, no dimensions.
$s = h/l$ = hydraulic slope, loss in head /ft.
T = absolute flowing temperature = 460+ °F.
T_0 = absolute base temperature = 460+ °F.
u = velocity, ft./sec.
v = average velocity, ft./sec.
v_{max} = maximum velocity, ft./sec.

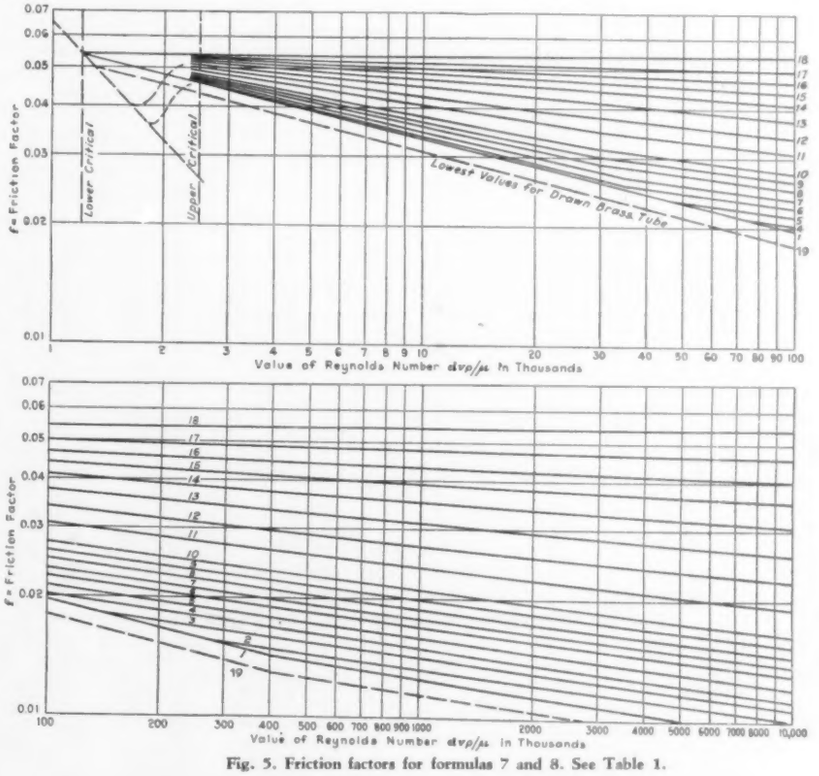

f = Friction Factor
Lower Critical
Upper Critical
Lowest Values for Drawn Brass Tube
Value of Reynolds Number dvρ/μ in Thousands
f = Friction Factor
Value of Reynolds Number dvρ/μ in Thousands

Fig. 5. Friction factors for formulas 7 and 8. See Table 1.

v_* = shear stress velocity, ft./sec.
y = distance from pipe wall, ft.
ΔP = loss in pressure, lb./ft.
μ = absolute viscosity, lb./ft.sec.
$\nu = \mu/\rho$ = kinematic viscosity, ft.²/sec
ρ = density, lb./ft.³
τ_0 = shear stress at pipe wall, lb./ft.²
Subscripts 1 and 2 refer to conditions at the upstream and downstream points, respectively.

curves for various pipe roughness will be displaced in a parallel fashion, instead of in the fanwise arrangement that experiment has shown to be correct; consequently the friction factors may be greatly in error if a wide range of the Reynolds number is used. So, however suitable the Hazen-Williams formula may be for water supply work, it can hardly be accepted by those already using the dimensional formula.

The Weymouth formula[17] is

$$Q = 18.062 \frac{T_0}{p_0} \sqrt{\frac{(p_1^2 - p_2^2)\, d^{5 1/3}}{G\, T\, L}} \qquad (13)$$

It is widely used in the calculations of large diameter transmission lines for natural gas, for which purpose it seems admirably suited[18,19]. Comparing the Weymouth formula with the dimensional formula, the friction factor of the former is found to be $\frac{c_c}{d^{1/3}}$, dependent on the diameter of the pipe alone, and quite independent of the Reynolds number. The effect of the $d^{-1/3}$ is to reduce the friction factor as the pipe size increases, which, of course, is a desirable matter. The similarity in composition of natural gases indicates that the differences in the viscosities of these gases will be slight and consequently the viscosity might well be represented by a constant value. If this is done, the velocity will be the only non-represented term in the friction factor of the Weymouth formula. Finally, if the velocity does not vary over too great a range, we have an explanation as to the apparent value of the Weymouth formula in natural gas transmission work.

As a matter of fact, a recently-made unpublished survey of the principal transmission lines indicates that for the average flow, 6.3% of the installations operate at Reynolds numbers of less than 100,000, 28.8% between Reynolds numbers of 100,000 and 500,000, 22.9% between 500,000 and 1,000,000, 39.0% between 1,000,000 and 5,000,000, and 3.0% above 5,000,000. Since the friction factors for the range in which most of the lines operate are relatively low down in the logarithmic chart, the change in the numerical value of the friction factor will be small over a relatively wide range of the Reynolds number. Thus the Weymouth formula, like the Hazen-Williams formula, is quite satisfactory for the use to which it is put, but would not be satisfactory for general application.

While Pigott's curves for the friction factor cover rough pipe, it will be of interest to observe some recent work of Nikuradse, reported by Prandtl[8], on the friction factor in artificially-roughened pipes. The results are shown in Fig. 5. The values r/k are the ratios of pipe radii to the size of the sand particles used for the roughness. Apparently r refers to the pipe radius which, naturally, is reduced by the larger sizes of sand grains; accordingly, a correction for this would tend to lower the curves somewhat, especially the curve for $r/k = 15$, which is somewhat above Pigott's rough pipe range. In correlating these tests, Prandtl found the relation between the logarithm of dimensionless "wall coefficient" $v_* k/\nu$, analogous to the Reynolds number, and the expression $\frac{1}{\sqrt{f}} - 2 \log \frac{r}{k}$ shown in Fig. 6. Other types of roughness are still to be investigated in Prandtl's Göttingen laboratory.

In conclusion it may be noted that the mechanism of pipe flow is by no means a simple affair. There are still many points to be cleared up, but work in hydraulic research is being actively conducted and the more important problems will undoubtedly be solved in due time. The study of the developments is sure to be interesting.

BIBLIOGRAPHY

[1]Lindquist, On Velocity Formulas for Open Channels and Pipes. *Transactions, World Power Conference,* Sectional Meeting, Scandinavia, 1933.

[2]Kemler, A Study of the Data on the Flow of Fluids in Pipes. Paper HYD-55-2. *Transactions of the American Society of Mechanical Engineers,* Vol. 55, 1933, No. 10, pages 7-32.

[3]Reynolds, Water—Direct and Sinuous Flow. *Philosophical Tranactions of the Royal Society,* Vol. 176, 1883, pages 935-84.

[4]Blasius, The Law of Similarity in Frictional Processes in Fluids. *Forschungsarbeiten auf dem Gebeite des Ingenieurwesens,* No. 131, 1913.

[5]Stanton and Pannell, Similarity of Motion in Relation to Surface Friction of Fluids. *Philosophical Transactions of the Royal Society,* A, Vol. 214, 1914, pages 199-224.

[6]Parry, On the Use of $\frac{vd}{\nu}$ as a Parameter in the Practice of Hydraulics. *Transactions, World Power Conference,* Sectional Meeting, Basle, Vol. 1, 1926, pages 749-58.

[7]Poiseuille, Recherches Expérimentales sur le Mouvement des Liquides dans les Tubes de Très Petits Diamètres. *Comptes Rendus,* Vol. 15, 1842, pages 1167-86.

[8]Prandtl, Neuere Ergebnisse der Turbulenzforschung. *Zeitschrift des Vereines deutscher Ingenieure,* Vol. 77, 1933, pages 105-14.

[9]Smith, Theory of Quantity-Rate Fluid Meters for Flow Through Pipes. Thesis, Univ. of Cal., 1932.

[10]Stanton, The Mechanical Viscosity of Fluids. *Proceedings of the Royal Society,* A, Vol. 85, 1911, page 366.

[11]Smith, Quantity-Rate Fluid Meters. *Transactions of the A.S.M.E.,* HYD-52-7b, 1930, pages 89-109.

[12]Stanton and Pannell, Similarity of Motion in Relation to the Surface Friction of Fluids. *Philosophical Tranactions of the Royal Society,* A, Vol. 214, 1914, page 199; and *Collected Researches of the National Physical Laboratory,* Vol. 11, 1914, page 293.

[13]Nikuradse, Gesetzmässigkeiten der Turbulenten Strömung in glatten Rohren. *VDI-Forschungsheft 356.*

[14]Handbuch der Experimentalphysik, Vol. 4, Part 4.

[15]Pigott, The Flow of Fluids in Closed Conduits. *Mechanical Engineering,* Vol. 55, Aug. 1933, page 497.

[16]Hazen and Williams, Hydraulic Tables, 1905.

[17]Weymouth, Problems in Natural Gas Engineering. *Transactions of the American Society of Mechanical Engineers,* Vol. 34, 1912, pages 185-231.

[18]Johnson and Berwald, Flow of Natural Gas Through High-Pressure Transmission Lines. *Reports of Investigations No. 2942, U. S. Bureau of Mines,* 1929.

[19]Berwald and Johnson, Factors Influencing Flow of Natural Gas Through High-Pressure Transmission Lines. *Reports of Investigations No. 3153, U. S. Bureau of Mines,* 1931.

Instrumentation Terms

To the Editor:

I read Mr. Paul MacGahan's letter of November fifth, as published in the December issue of your paper, with considerable interest.

The trouble seems to be that in the earlier days of instrumentation the proper care was not used and when attempts were made to correct this it became very difficult in view of the fact that the large majority of those who use electrical instruments do not belong to the AIEE and do not very much care what the Instrument and Measurements Committee of the organization proposes. Those of us who have been in the instrument business for some years can well remember that a watthour meter was a recording wattmeter. Naturally the early manufacturers of what we today call recording meters had to use a name to differentiate the instruments from the integrating type or what we now call watthour meters.

You would be surprised, if you were selling as the writer does both recording instruments and watthour meters, to find out the degree of confusion these exists in the minds of many engineers and electricians. I get inquiries for recording wattmeters when they want watthour meters and inquiries for graphic watthour meters and recording watthour meters, and it is a mighty difficult task sometimes to find out what the inquirer really wants.

The situation with reference to permanent-magnet moving-coil instruments is likewise the result of some manufacturers' attempts to differentiate their product from the product of another manufacturer. Those whose memories go back twenty-five or more years will recollect that when Dr. Weston first put his permanent-magnet moving-coils on the market they were generally referred to as Weston moving-coil instruments. Other manufacturers of similar instruments could not very well use Dr. Weston's name, and therefore took the name d'Arsonval because at that time due to the d'Arsonval galvanometer the name was associated with the permanent-magnet moving-coil type of instrument.

We must therefore be patient because it is going to take a long time before the general run of men can remember that a meter is a meter and an instrument is an instrument, and never the twain should meet excepting in an indicating voltmeter or similar instrument.

New York, Dec. 21, 1934 HERMAN H. STICHT

An Air-damped Accelerometer

By MAURICE J. BREVOORT*

AN acceleromoter employing air damping has been developed by the National Advisory Committee for Aeronautics as the result of an investigation begun primarily to eliminate the dependence of damping characteristics upon temperature usually experienced when fluid damping is used. The accelerometers formerly used by the N.A.C.A. in flight testing of aircraft consisted essentially of an oil-damped cantilever spring the motion of which was optically transmitted to a moving photographic film.

On account of its small variation in viscosity with temperature and its small mass effect, air was adopted as a damping fluid and the problem became one of arranging and altering the instrument to the best advantage.

In the course of this development a study similar to the one made by Bouny[1] was made to determine the lowest natural frequency that could be used for the deflecting unit. This study proved that no one frequency would be satisfactory for all conditions, but that an accelerometer, to be most satisfactory, should be designed for the particular use intended. An accelerometer used for aircraft manoeuvers might have a natural frequency between 10 and 15 vibrations per second, which would be high enough to record the accelerations faithfully and would also be low enough to fall below the resonant vibrations set up in the airplane structure by the motor and propeller.

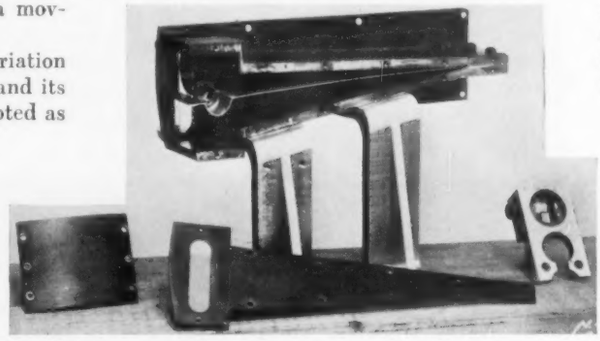


Fig. 1. Light-vaned accelerometer unit.

At the present time three types of accelerometers are being used by the N.A.C.A.: (1) an oil-damped instrument having a natural frequency of 60 vibrations per second; (2) a very light-vaned air-damped instrument, the natural frequency of the spring being 12 vibrations per second, and (3) a heavy-vaned air-damped instrument with a natural frequency of 4 vibrations per second.

Type 1 is useful for measuring accelerations in landings; type 2 is useful for general manoeuvers and easy landings; type 3 was designed for either very small accelerations of long duration or for visual reading. Each type meets a special need and in no way duplicates the functions of the others. It is quite probable that for particular problems other units will be found necessary to obtain the highest accuracy.

Type 2, shown in Fig. 1, has a light vane about 0.009″ thick. The vane is mounted in a case with 0.003″ to 0.010″ clearance on the side and end. The clearance is adjusted to give critical damping. On the vane is a lens that focuses the image of a lamp filament onto a film. Any movement of the vane thus gives a proportional movement of the image from the lamp filament. By a

*Associate Physicist, National Advisory Committee for Aeronautics, Langley Field, Va.

[1]Accelerograph for Airplane Manoeuvers, by F. Bouny, Belgian Service Technique de L'Aéronautique, 1927.

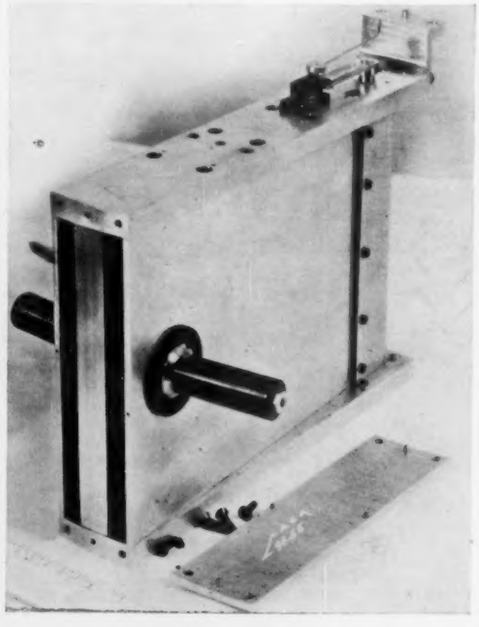


Fig. 2. Heavy-vaned accelerometer unit.

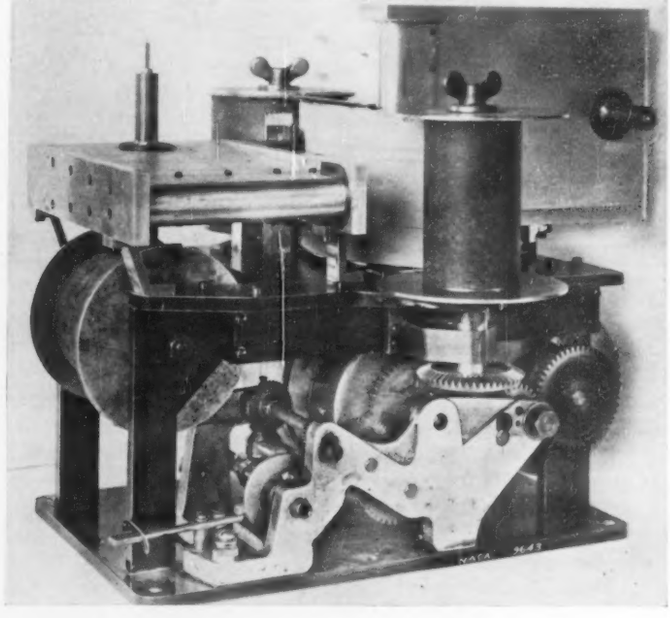


Fig. 3. Two-component accelerometer.

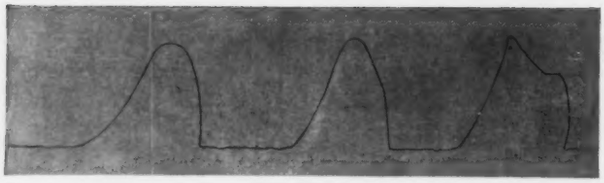


Fig. 4. Record of slow airplane manoeuver taken with heavy-vaned accelerometer. (Half size.)

proper choice of focal length of the lens and dimensions of the case a considerable range of amplification of the movement of the vane is available. The whole unit is self-contained and dust-proof. When it is once assembled it needs no further servicing other than the occasional replacing of a lamp.

Type 3 (see Fig. 2) has a heavy vane restrained by an axle in ball bearings at one end and by two spiral springs at the other. An acceleration rotates the vane about its axis. The rotation of the vane is amplified by suitable gearing to give the desired movement of an arm.

APPENDIX—PRINCIPLES

The fundamental principles involved in the performance of an accelerometer together with a discussion of the corrections and errors inherent in certain types of accelerometers are available elsewhere.[2] The discussion given here will apply primarily to an accelerometer of type 2. The equation defining the motion of a vane of such an accelerometer is

$$\frac{d^2y}{dt^2} + K\frac{dy}{dt} + 4\pi^2 f_2{}^2 y = a \sin 2\pi f_1 t \quad . \quad . \quad . \quad (1)$$

where y = deflection of the vane.
t = time.
K = damping coefficient.
f_2 = the natural frequency of the vane.
f_1 = the frequency of the imposed acceleration.
a = the magnitude of the imposed acceleration.

The solution of equation (1) for the condition of critical damping, $K = 4\pi f_2$, is

$$y = ae^{-2\pi f_2 t}\left[\frac{f_1 f_2}{2\pi^2 (f_2{}^2 + f_1{}^2)^2} + \frac{f_1 t}{2\pi (f_2{}^2 + f_1{}^2)}\right] + a\frac{(f_2{}^2 - f_1{}^2)}{4\pi^2 (f_2{}^2 + f_1{}^2)^2}\sin 2\pi f_1 t - a\frac{f_2 f_1}{2\pi^2 (f_2{}^2 + f_1{}^2)^2}\cos 2\pi f_1 t \quad . \quad . \quad . \quad . \quad (2)$$

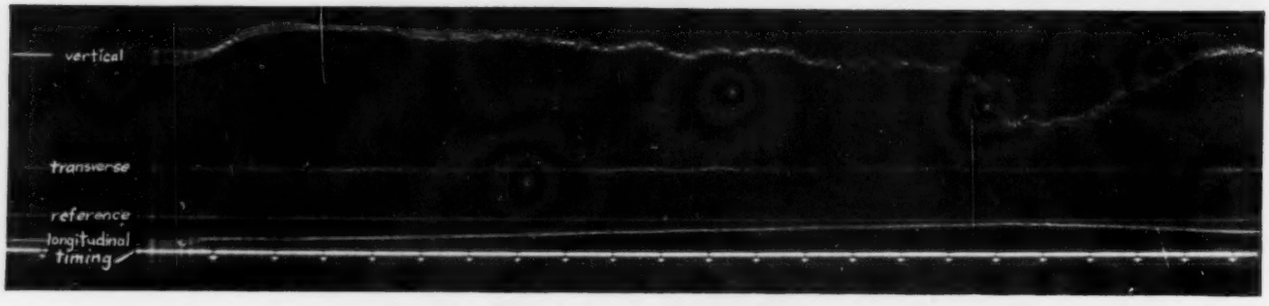


Fig. 5. Record of dive and recovery from dive with the three-component accelerometer. (Three-quarter size.)

The arm can be used either for visual indication or for recording with a stylus on waxed paper. The vane is adjusted to critical damping by a proper choice of clearances. In this instrument the vane is made heavy to minimize the tendency to show a double zero when recording with the stylus on waxed paper.

The instrument shown in Fig. 3 is furnished with two units of the type shown in Fig. 2. Being designed for the recording of airship manoeuvers, a spring motor was substituted for the electric drive as a safety measure.

Fig. 4 is a reproduction of the record made on paraffined paper by one of the units of such an instrument recording a very slow airplane manoeuver. Fig. 5 shows a photographic record from a 3-component accelerometer using the less sensitive unit shown in Fig. 1 taken during an airplane dive and the subsequent recovery from the dive.

CONCLUSIONS

The simplicity and ruggedness of the air-damped accelerometer results in a low amount of service required and reliable performance.

Critical air damping makes it possible to correct the results to secure the true acceleration throughout an aircraft manoeuver. Air damping also eliminates the necessity of correcting for temperature changes.

The natural frequency has been chosen at a compromise value below engine and airplane resonance frequencies yet high enough to record accurately the manoeuvers for which the instrument was designed. This choice of natural frequency also eliminates the need of a damping device between instrument and airplane structure.

The acceleration is given by $4\pi^2 f_2{}^2 y$ when $\frac{d^2y}{dt^2}$ and $K\frac{dy}{dt}$ are both assumed to be zero.

Fig. 6 is the plot of an imposed acceleration and the response of a typical accelerometer. For this plot $f_1 = 1$ vibration per second; $f_2 = 10$ vibrations per second; and $a = 1$. The value of f_1 was taken as 1 because it was found after studying the records for a large number of representative airplane maneuvers that the time taken in going from neutral position to maximum position of the vane is usually of the order of 0.25 second. Thus, if this acceleration were assumed as a first approximation to change sinusoidally the 0.25 second would cor-

(Continued on page 20)

[2]Accelerometer Design, by F. H. Norton and Edward P. Warner. N.A.C.A. Report No. 100, 1921.

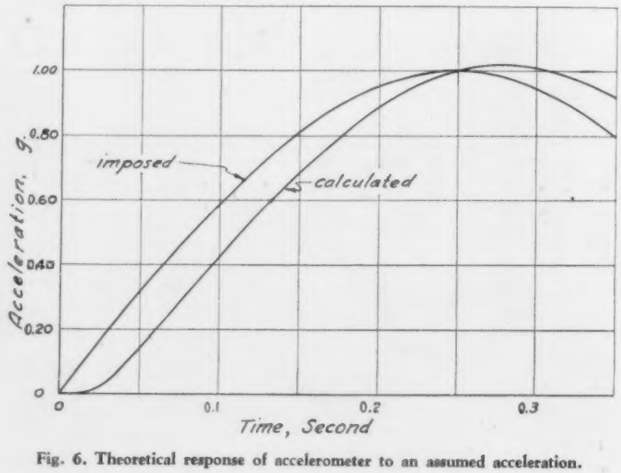


Fig. 6. Theoretical response of accelerometer to an assumed acceleration.

Recording Electrical Instruments*

FIRST INSTALMENT

Electrical-relay Types

By PERRY A. BORDEN† and M. F. BEHAR**

1. General Characteristics

An outstanding characteristic of the recorders now to be discussed is that the measuring element is entirely relieved of the function of moving a pen or other marking element across a chart. This work is done by a servomotor or power device *commanded* by the measuring element, as in automatic control systems. Power for driving the marking element being derived from an external supply, the measuring element may be constructed to have any degree of accuracy characteristic of its type. In voltmeters, ammeters, wattmeters and all other types of measuring elements in which the dynamometer principle may be used, this makes possible the application of the zero-reading method. In this method the relative position of the fixed and moving parts always is the same at the time of actually performing measurement, so that geometrical configuration of parts does not affect proportionality and some serious sources of error are eliminated.

While measuring elements in which the measured magnitude is normally represented by a mechanical force (such as galvanometers, ammeters, wattmeters, etc.) are preferably developed in the zero-reading form when used in relay-type recorders, the relay principle also makes possible the recording of measurements obtained by the use of balancing networks, chief among which are the potentiometer and bridge circuits. Since these circuits are adaptable to the determination of many magnitudes not in themselves of a basically electrical nature (see the October and November articles) there is thus thrown open a vast field of electrical recording, and many measurements otherwise only performed in the laboratory by skilled technicians are thoroughly "industrialized."

Again, since the measuring element is only required to actuate a relay, and ordinarily to deflect through a small angle ($<5°$) the power consumption of the element can be materially reduced, which makes it easier to compensate for temperature, frequency and other errors, beside reducing the burden which instrument transformers may be called upon to carry.

A further feature of the relay principle lies in the fact that because of the removal of mechanical limitations and because of the larger forces available it is possible to construct such instruments with much longer scales than otherwise available, so that the chart width is only limited by the hygroscopicity of paper as discussed in Section 3 of the preceding article.

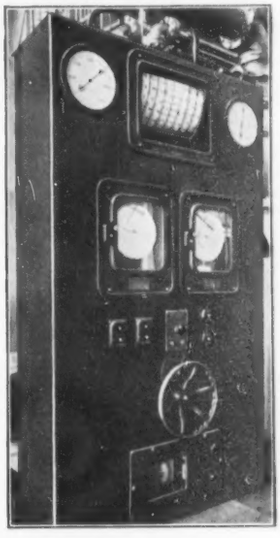
While the time element inseparable from the operation of most relay recorders means that sudden fluctuations in the measured magnitude may not be recorded, this is generally an advantage; and for most purposes the slight delay is more than compensated for in precision of measurement.

General Principle: A sensitive measuring element normally in a state of equilibrium controls a follow-up or balancing system, so that upon a change in the value of the measured magnitude the balance is disturbed and there are called into service agencies tending to apply corrective measures reducing the effective reaction of the measuring element to zero and restoring a condition of balance. The effective reaction may be reduced to zero in any one of three ways:

*Thirteenth chapter (XLI) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Béhar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. A complete chapter of this new handbook is published in each issue of *Instruments* throughout 1934 and 1935. Each chapter is subjected to a final revision, and then set in type, shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about Jan. 1, 1936.

†Member A.I.E.E. **Editor, *Instruments*

FOR BOILER CONTROL



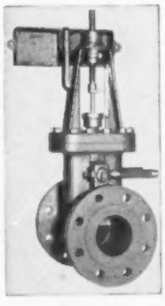
THE BAILEY BOILER PANEL gives complete information for controlling boiler operation. It contains the Bailey Boiler Meter, a Bailey Fluid Meter with which is combined a Boiler Water Level Recorder, and a Bailey Multi-Pointer Gage. The operator has everything right before him to obtain the desired capacity and best efficiency at all times. Request recommendations for your boilers.

PRESSURE GAGE

Extremely accurate gages embodying the dead weight gage tester principle are available in several sizes up to 36" in diameter for indicating at remote points the pressure of steam, water, gas, etc. These gages can be used with any pressures and are particularly suitable for magnified ranges. Ask for Bulletin No. 70.

LONG DISTANCE INDICATOR

Bailey Meter Selsyn Operated Equipment for recording and indicating pressure, temperature, draft, liquid level, etc. at any distance from the source is highly accurate and reliable. Described in Bulletin No. 110.



ADJUSTABLE ORIFICE

The Bailey Adjustable Orifice is for use with Fluid Meter installations where accurate measurements are desired over a flow range of as wide as 160 to 1. Ask for details.

BAILEY METER CO.
1041 IVANHOE ROAD
CLEVELAND, OHIO

THE ACCEPTED FUEL FLOW INDICATOR

The Research Indicator Type 18

The Standard in Automotive Laboratories

The Research Indicator Type 5

A New Instrument for

MOTOR CARS
TRUCKS
BUSES
AIRPLANES

Graduated in gallons per hour and miles per gallon

Unaffected by vibration

Air Flow Indicators
Dynamometers
Engine Indicators
Fuel Flow Indicators
Magnetic Thickness Gauges
Proving Stands
Railway Motor Car Recorders
Slow Motion Study Equipment
Sound Indicators
Speed Indicators and Recorders
Vibration Indicators and Recorders

Write for information

COMMERCIAL ENGINEERING LABORATORIES

4612 WOODWARD AVENUE
DETROIT, MICHIGAN

TABLE 41-1—RELAY-TYPE RECORDERS

Type	Maker	Designation	Date	Measuring Element	Servomotor	Scale Length
Electrical	Cambridge	Callendar	1899	Bridge and Potentiometer	Spring & Diff'l Gear'g	7⅞"
	Olivetti		1900	Voltmeter—Ammeter—Wattmeter	Ferraris Motor	5⅞"
	Westinghouse	Original Type	1905	Voltmeter—Ammeter—Wattmeter	Solenoids	5¼"
	Westinghouse	Type "R"	1911	P-F. Meter—Frequency Meter	Motor	5¼"
	Canadian W'house	Type "G"	1925	Wattmeter	Motor	5¼"
	Everett-Edgcumbe	Relay Grapher	1926	Voltmeter—Ammeter—Wattmeter	Motor	4"
	Westinghouse	Centrif'l Frequency Rec'r	1928	Synchr. Motor Driving Fly-ball Tach	Motor	5¼"
	Uehling	Self Contact	1930	Bridge and Potentiometer	Motor	(Strip 7" (Round 3½"
	Bailey	Galvatron	1934	Bridge and Potentiometer	Telechron Motor	4¼"
	Bristol	Wide Chart	1935	Bridge and Potentiometer	Motor	11"
Mechanical	Leeds & Northrup	Recording Potentiometer	1910	Bridge and Potentiometer	Motor and Clutch	9⅞"
	Wilson-Maeulen	Self-balancing Potentiometer	1929	Bridge and Potentiometer	Motor and Clutch	11"
	Leeds & Northrup	Micromax	1931	Bridge and Potentiometer	Motor and Clutch	9⅞"
	Brown	Temperature Recorder	1931	Bridge and Potentiometer	Motor and Clutch	9⅞"
	Foxboro	Temperature Recorder	1933	Bridge and Potentiometer	Motor and Clutch	11"
	Cambridge	Recording Potentiometer	1933	Bridge and Potentiometer	Motor and Clutch	7⅛"
Electronic	General Electric	Photoelectric Recorder	1931	Galvanometer	Electrodynamometer	4"
	Westinghouse	Electronic Recorder	1932	Galvanometer	Electrodynamometer	4"
	Tagliabue	Photoelectrically-balanced	1932	Bridge and Potentiometer	Telechron Motor	10"
	Leeds & Northrup	Speedomax	1933	Bridge and Potentiometer	Motor	9⅞"

(1) By shifting the "stationary" part of a measuring unit until the moving element is brought to a position corresponding to equilibrium.

(2) By introducing a mechanical force to oppose the torque of the measuring element.

(3) By introducing into the electrical circuit of the measuring element an electromotive force opposing and reducing to zero the measuring torque.

In any of these cases the automatically effected adjustment is accompanied by a displacement of some mechanical part of the instrument, with which is associated a pen or other device which provides on a paper chart a record of the amount of corrective effort necessary to restore the equilibrium, and thus an indirect measure of the magnitude.

According to the method by which the measuring element commands the mechanism which positions the writing element, relay-type recorders may be broadly classified under three heads:

(1) *Electrical*, in which the deflecting part of the measuring element directly actuates electrical contacts, thereby commanding the restoring mechanism.

(2) *Mechanical,* in which the deflecting member is periodically engaged by a moving part, which through further mechanical or electrical means acts to restore the balance.

(3) *Electronic,* (*a*) in which the deflecting member moves at all times without restraint and influences the restoring mechanism either by inductive coupling or by a beam of radiant energy, a system of electron tubes generally being included in the circuit; (*b*) in which there is no galvanometer, the command being purely electronic.

This order—electrical, mechanical, electronic—is that of the historical development of relay-type recorders and will be followed in this article. Within each of the three divisions, too, the various types will be dealt with in chronological order. These various types being the different *makes,* we shall not hesitate to identify each particular one with the individual manufacturer responsible for its development. Since relay-type recorders developed for pyrometry, etc., are described at length in other volumes of this Manual, they will be described but briefly here. Because of the importance of relay-type recording electrical instruments, the historical aspect as well as the technical development will receive more attention in this article than they do in others.

2. Electrical-relay Types

(a) Callendar—Cambridge

The earliest known electrical relay type of recording instrument is that developed by Professor H. L. Callendar in England about 1899, appearing first as a recording slide-wire bridge, and later as a potentiometer, and as a combination bridge and potentiometer. Designed primarily for the measurement of temperature, this instrument represents a pioneer attempt to bring practical pyrometry out of the laboratory into the plant. A diagram of the circuit of this instrument in the form of a self-balancing bridge to be used as a resistance thermometer is shown in Fig. 41-1 and a photograph of the instrument as manufactured by Cambridge is shown in Fig. 41-2.

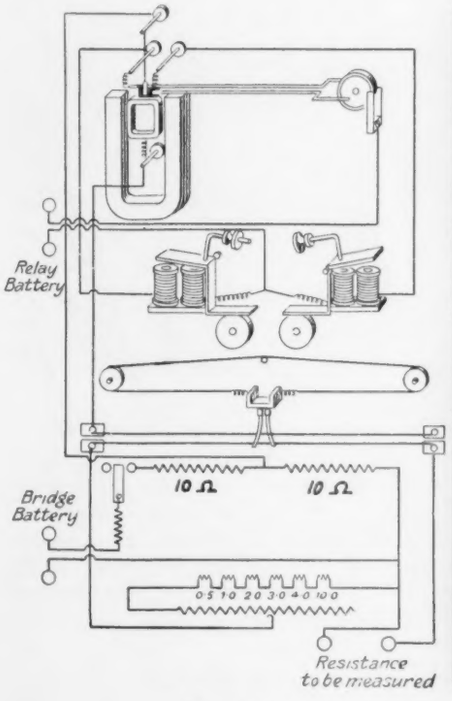


Fig. 41-1

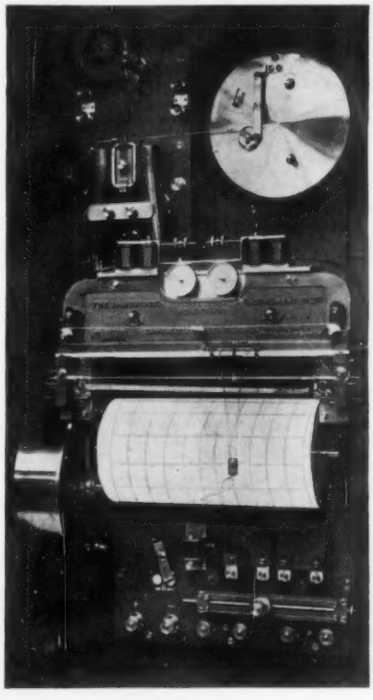


Fig. 41-2

The bridge circuit is made up of the two 10-ohm units shown, which correspond to the "A" and "B" arms of the regular Wheatstone bridge network. The "R" arm is made adjustable, and the temperature-sensitive "bulb" constitutes the resistance to be measured. Compensating leads correct for line temperature effects. Balance is maintained by a contact engaging a straight slide wire, which contact also carries a recording pen. The diagram shows two slide wires: one of these serves merely as a connection between the slider and the galvanometer circuit, instead of a flexible lead. The galvanometer, of the d'Arsonval type, has a pointer with a forked end containing two contacts. Sticking of the contacts is prevented by a unique method: a disk having sil-

Announcing a

Home Study Course

in the Theory and Technique of

INVENTIVE PRACTICE

Invention begins with
AN IDEA
Development of an invention is
A CHAIN OF IDEAS
For the first time in the history of education it has become possible and expedient to teach how to
PRODUCE MORE AND BETTER IDEAS

It is Ideas that move the world

Based on Trofimov's Theory of The Technical Problem and Its Solution, this course provides for the first time an opportunity for the designer to learn HOW TECHNICAL IDEAS COME TO US AND HOW TO MAKE THEM COME

This course had its inception eighteen years ago when Mr. Trofimov's inventions were being installed in R.I. (Russian Imperial) Navy submarines and inventors flocked to him with their ideas in various stages of development. During these eighteen years he perfected his system, used it in creating new machines and automatic control systems, taught it to others (with "miraculous" results), formulated it into a Home Study Course and finally revised and perfected this course to make it a Key and a Tool for ANY type of technical mind.

Whether your mind is of the "plugger" or of the "flash" type—whether your work is research or development—electrical, chemical or mechanical—you can make your mind produce more and better technical ideas by studying this course.

Engineering degrees are not needed to study this course. It is not what you know that counts in producing ideas but what you can do with that knowledge. The ability to solve technical problems must be—and can be—acquired. This course develops your idea-producing ability.

WRITE FOR FULL PARTICULARS TO

Trofimov School of Inventive Practice, Inc.

3859 Northampton Road
Cleveland Heights, Ohio

It is Ideas that Move the World

"AUTOSYN"

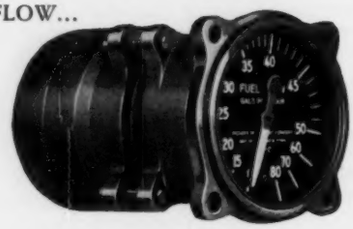
Self-Synchronizing Motor

As Remote Indicating mediums in connection with...

TEMPERATURE...

PRESSURE...

FLOW...



And hundreds of applications where Remote Indications are desired. • Operates 32 volts A. C., 60 cycles, single phase • Two or three Indicators may be operated from a single transmitter • Write for data.

PIONEER INSTRUMENTS

Pioneer Instrument Company Incorporated

BROOKLYN, NEW YORK

A Subsidiary of the Bendix Aviation Corporation

vered edges constantly rotates within the forked tip of the pointer, giving a sliding action whenever either side of the fork engages the disk. The servomotor circuit is completed through two small electromagnets which, when energized, release brakes on the free ends of two differential gearings, continually subject to torque from a spring-driven motor and so arranged that upon either brake being released the gear train at once rotates in a corresponding sense and rotates a small windlass upon which is wound a cord, thus moving the sliding contact and the attached pen in a direction to restore the balance of the bridge. The scale length is 7⅞ inches.

(b) Olivetti

Another early electrical-relay recorder is the Olivetti, developed by Arcioni in Italy about 1900. A diagram of this instrument is shown in Fig. 41-3. The measuring element *A*—an ammeter, a voltmeter or a wattmeter—uses the electrodynamic principle, the control force being derived from a spiral spring *B*. Deflection of the moving element actuates contacts at *C* which control a

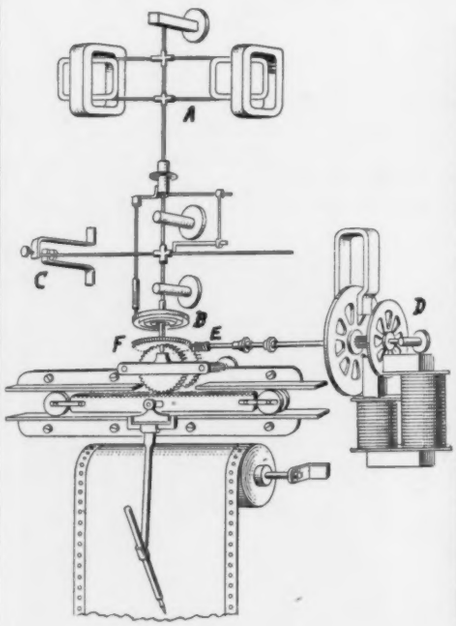


Fig. 41-3

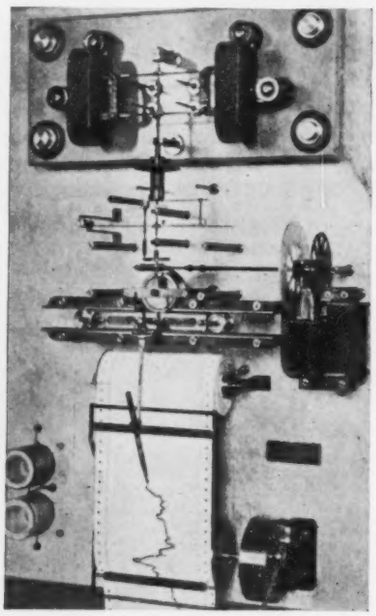


Fig. 41-4

small disk-type motor *D*, driving worm *E* and wheel *F* to which is attached one end of the control spring. Thus the motor adjusts the control torque on the moving element until a state of balance is attained, and a pen provides on a strip chart an indication of the control torque and hence of the measured value. The chart has a scale of rectangular coördinates approximately 6 inches wide. Fig. 41-4 is reproduced from a 1902 Olivetti booklet describing numerous refinements, such as adjustability of pen speed across chart, in which a manufacturer could take pride today.

Both the Callendar and the Olivetti recorders as described above have been superseded by modernized models, but they represent epoch-making advances. In the field of recording bridges and potentiometers the Callendar recorder stood practically alone for ten years, while in many generating stations throughout Europe the old Olivetti instruments produced records with a trustworthiness seldom surpassed today. Outside of longer chart scales and of much more rugged mechanical construction, it must be admitted that the great advances in relay type electrical recorders these last twenty years have not resulted in a materially better measuring performance than that of the old Callendar-Cambridge and Arcioni-Olivetti instruments.

"The Most Valuable Book in My Technical Library"

So say many users of **Fundamentals of Instrumentation,** the primer of Measurement and Control, which contains *all* of the *essential* foundations on which engineers and executives can build efficiency with instruments. Two dollars postpaid. The Instruments Publishing Co., 330 W. 42nd Street, New York City.

(c) Westinghouse—Original Type and "Type R"

The best-known electrical relay recorder is the Westinghouse, widely used here and in many foreign countries for recording current, voltage, power, frequency, power factor and other industrial electrical magnitudes. The early form, brought out in 1905, embodied a simple arrangement of opposed solenoids which acted through a straight-line motion to position the pen. The measuring element in the ammeter, voltmeter, wattmeter, and in the original frequency meter took the form of a spring-controlled Kelvin balance having on its moving element a contact which, co-acting with a pair of stationary contacts, energized either one of the solenoids, moving the pen on the chart and adjusting the tension on a spring opposing the torque developed in the measuring element. The power factor meter embodied a similar servomotor system; but the measuring element being inherently free of control forces, and being of the direct-deflecting type, a true follow-up system was used, the "fixed" contacts being carried by the recording mechanism, and positioned thereby until a point was reached corresponding to the angular position of the deflecting element, and thence to the power factor of the system. (The type of measuring unit used was described in the July article.)

About 1911 the solenoid form of servomotor was replaced by the more conventional motor-operated form, the contacts on the measuring element commanding a small motor, and the motor in turn positioning the pen by means

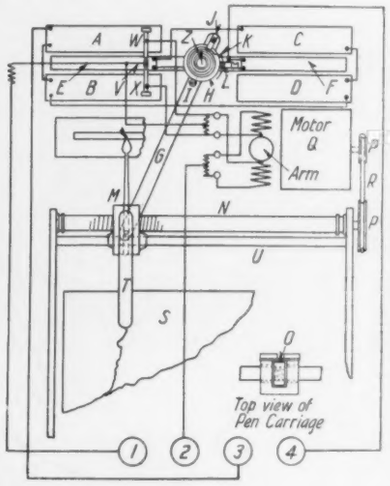


Fig. 41-5

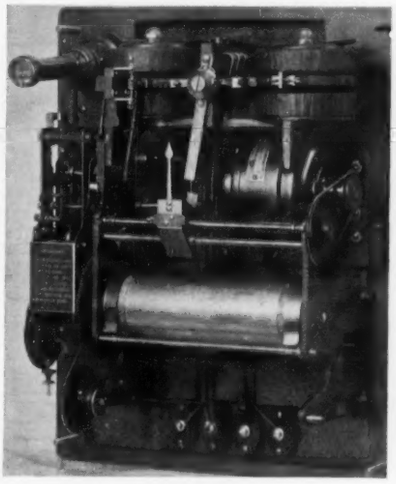


Fig. 41-6

of a screw. The helical control spring is now replaced by a simple spiral spring concentric with the axis of rotation of the balance element, having one end attached to the moving part of the balance and the other to the pen mechanism. Figs. 41-5 and -6 bring out the essential features of late-model Westinghouse "Type R" recorders.

The Westinghouse recording power factor meter in the newer ("Type R") form embodies an interesting system of measurement, particularly adapted to instruments of the relay type. Fig. 41-7 is the circuit diagram: A measuring element of the Kelvin balance class is used, the current coils being connected as a wattmeter, and the voltage circuit energized from a small phase-shifting transformer. The servomotor mechanism adjusts the phase position of the output of this transformer to a condition of zero torque on the measuring element, which represents a quadrature relationship between the equivalent single-phase voltage and single-phase current of the load. The pen being mechanically attached to the phase-shifting transformer, there is provided an indication of the power factor of the load. This system of determining power factor is suitable not only for balanced loads but for unbalanced loads within the meaning of the definition given in the September article.

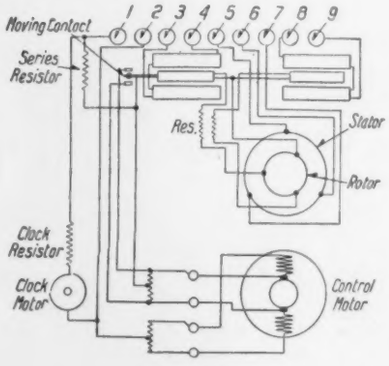


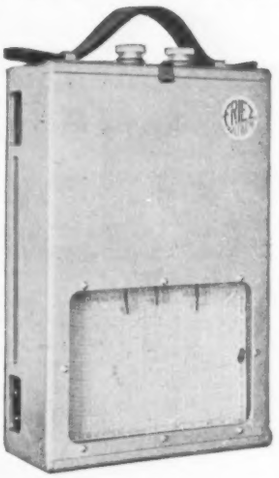
Fig. 41-7

New FRIEZ

Small, Light

low-cost, high accuracy

PORTABLE RECORDERS



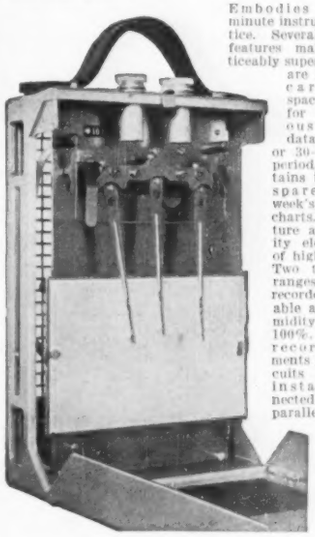
For temperature, for humidity, for operation records and for any desired combination of any two or of all three.

Easily portable: weight 52 ounces.

Slip into overcoat pocket: 5½x8½x 2¼ inches.

Rugged and reliable, yet sensitive and accurate. Built by FRIEZ—for 50 years makers of instruments for U.S. Weather Bureau, Navy, etc.

An ideal instrument for all concerned with air-conditioning, heating, ventilating, refrigeration, industrial processes and operations. Indispensable for field engineers and service men.



Embodies up-to-the minute instrument practice. Several unique features make it noticeably superior. Charts are 3x5" index cards with space on back for simultaneous general data. 10-hour or 30-hour chart period. Case contains ink supply, spare pen and week's supply of charts. Temperature and humidity elements are of highest grade. Two temperature ranges on each recorder, changeable at will. Humidity range 0-100%. Operation recording elements for all circuits met with, instantly connected. Series or parallel.

3-pen Type R-4

PRICES FROM $45 LIST

JULIEN P. FRIEZ & SONS, Inc.

(A Subsidiary of the Bendix Aviation Corp.)

BALTIMORE, MARYLAND

● ● ● ● **SEND COUPON** ● ● ● ●

Julien P. Friez & Sons, Inc.
Baltimore, Md.

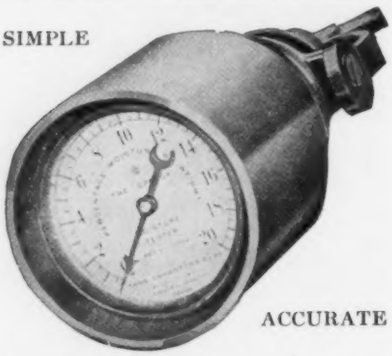
Send details new Friez Type R Recorders

Name.....

Address.....

USE THE "SPEEDY"
MOISTURE TESTER

SIMPLE

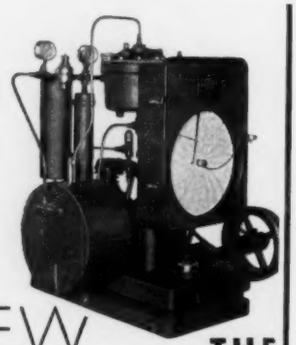


ACCURATE

For testing Sand, Ganister, Coal, Coal-dust, Coke, Oxides, Powdered Fuel, Tobacco, Cotton, Wool, Grain, Paper, Blacking, Abrasives, Materials in process.

A Plant Instrument: can be taken to shop, foundry, etc. ¶*Really Speedy*: from 30 to 60 seconds as a rule. ¶*Ranges* for all YOUR materials.

The Alpha-Lux Co., Inc.
192 FRONT ST. NEW YORK



NEW . . THE
GRAVITOMETER

A new device . . . a new method . . . now makes possible the accurate determination of specific gravity of gases by correcting *automatically* for variations in both atmospheric pressure and temperature. Thus laboratory accuracy is obtained readily under actual production conditions. Bulletin E-21 mailed on request.

AMERICAN METER COMPANY
INCORPORATED
Measurement and control of Gas, Oil, Steam, Air and Liquids
METRIC METAL WORKS *ERIE, PENNSYLVANIA*

158

In Westinghouse recording voltmeters, ammeters and wattmeters, a convenient feature consists of "self-calibrating" weights, one of which is supplied with each instrument and stamped with a corresponding serial number. With the measured circuit cleared and the servomotor circuit left on, this weight is hung on a hook provided on the moving element, whereupon the pen should take up a position at the mid-point of the scale, thus providing an approximate calibration of the instrument.

(d) Westinghouse—"Type G"

In the Westinghouse voltmeters, wattmeters and ammeters thus far described, the control force is derived from a spring, helical in the original form and spiral in the more recent types. An interesting modification, approaching more nearly the true Kelvin balance, is found in "Type G" built by the Canadian Westinghouse Co. on special order for important applications where the billing of large power loads is based primarily on recording wattmeter charts. In this instrument (see Fig. 41-8) the control torque is derived from a weight W_1 positioned along a rail on the moving part of the measuring

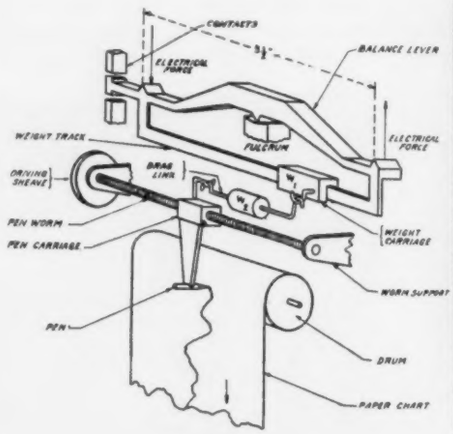


Fig. 41-8

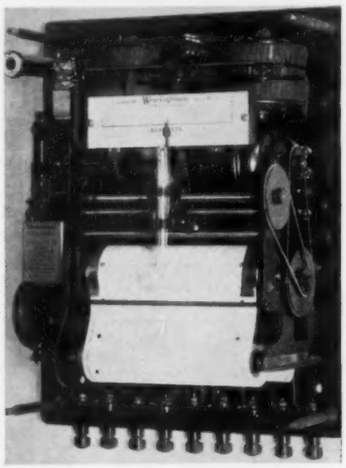


Fig. 41-9

element by the control mechanism which moves the pen. It will be seen that the scale of such an instrument is inherently uniform in its proportionality. An effective adjustment of scale length is provided by the weight W_2, carried on the link between the pen carriage and the main sliding weight. By moving W_2 to the right or left relatively to the link a greater or less proportion of its weight acts in conjunction with W_1, thus directly affecting the distance the pen carriage must be moved in order to counterbalance a given electromagnetic force in the measuring element. Fig. 41-9 shows the wattmeter of this

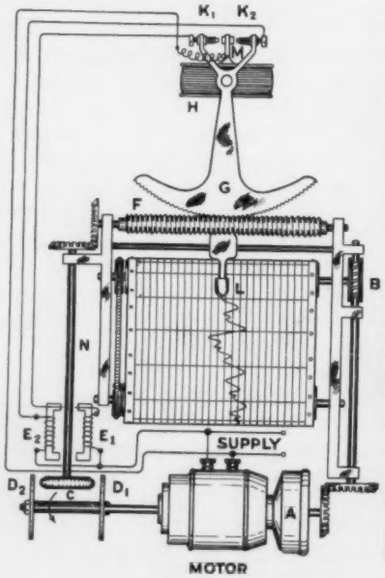


Fig. 41-10

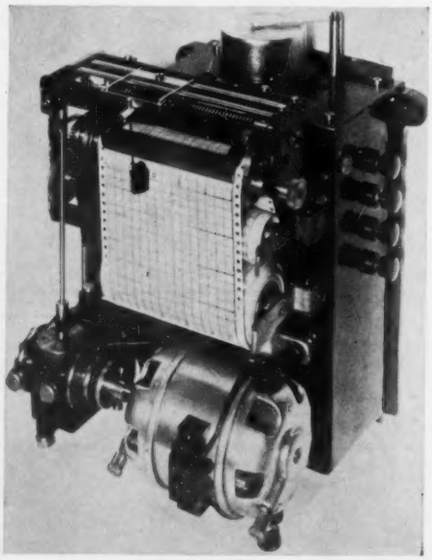


Fig. 41-11

type. These instruments may readily be provided with weights for suppressing the zero; and, there being no springs involved in the calibration, the amount by which the zero may be suppressed is limited only by the current-carrying capacity of the windings. Large totalizing wattmeters embodying similar principles will be discussed in a later article.

(e) Everett-Edgcumbe

This modern (1926) English instrument was primarily designed for recording electrical magnitudes but is used also as a speed recorder, etc. Fig. 41-10 shows its principle. Deflecting member M through contact K_1 (or K_2) energizes electromagnet E_1 (or E_2) thereby attracting steel rod N right (or left) to engage leather-rimmed wheel C with continuously-running disk D_1 (or D_2), thereby through worm F re-positioning both pen L and the pair of contacts until the circuit is broken at K_1 (or K_2), whereupon N and C return to vertical and the action ceases. The drive motor not only acts as a servomotor but drives the chart. It may be equipped with a centrifugal governor (A) whether it is supplied by direct or alternating current, but in the latter case a synchronous motor is preferable where the supply frequency can be relied upon for time-keeping. Fig. 41-11 shows a typical Everett-Edgcumbe "Relay Grapher." The measuring element being of the direct-deflection type and the recording mechanism being of the follow-up type, these instruments are made up not only as recording ammeters, wattmeters, etc., but as recording power factor meters, frequency meters, etc.

(f) Westinghouse—Centrifugal Frequency Recorder

Whereas the original Westinghouse recording frequency meter employed a Kelvin balance type of movement, with opposed elements energized through circuits of differing time constants (see August article) there is available since 1928 a type, Figs. 41-12 and -13, which employs a mechanical method whereby the instrument is literally a recorder of the velocity of a small synchronous motor driven from the source whose frequency is to be recorded. This motor, of the vertical-shaft type, operates a fly-ball governor whose reaction is opposed

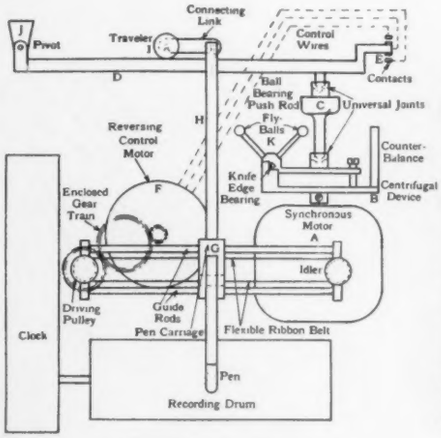


Fig. 41-12

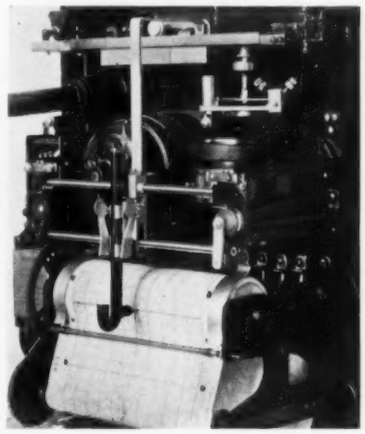


Fig. 41-13

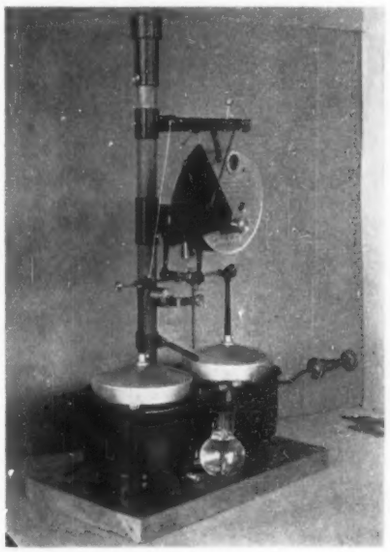
by the sum of the moments of lever D and of traveling weight I, the latter attached to the writing element. Contacts associated with the centrifugal member command the servomotor (a reversing type motor) in a sense to restore the equilibrium of the system; and the pen, moving in proportion, provides a record of the frequency. Because traveling weight I corresponds to the "rider" of a laboratory equal-beam balance without being necessarily delicate (the centrifugal element being relatively powerful) high sensitivity is attainable, so that the instrument may be obtained with a range of 2 cycles for the whole scale in the 60-cycle range, as compared with 16 cycles in the electrical balance type.

(g) Uehling

Brought out in 1930 for industrial pyrometry applications, the Uehling Instrument Co.'s "Self Contact Potentiometer" embodies interesting electrical features. The "self-contact" feature, see Fig. 41-14, is a pair of battery circuits whereby, as soon as unbalance in the thermocouple measuring circuit causes

ANUBIS

Recording Gas Gravitometer



A direct-weighing instrument of demonstrated accuracy and reliability, producing a temperature-compensated record of specific gravity of gas from a continuously flowing sample. Indispensable in the accurate measurement of large volumes and as a record of heat values.

Produced in the Laboratory of

GEORGE SYDNEY BINCKLEY C. E.
857 SOUTH SAN PEDRO ST., LOS ANGELES, CALIF.

The
Electronic Switch

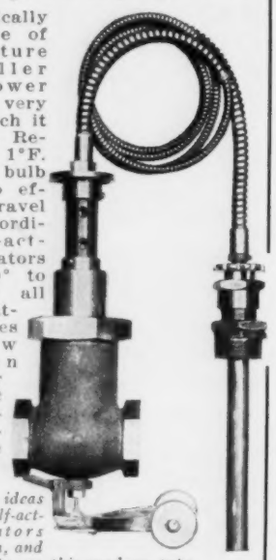
● The Type 143 Electronic Switch is a new development which greatly increases the value of the cathode ray oscillograph by permitting simultaneous observation of any two voltages or current phenomena. It can be used to compare the waveform and phase of two voltages or currents from different parts of the same circuit or compare the wave form of a standard wave and any other wave.

● Write for complete information on this device and associated cathode ray tube equipment.

ALLEN B. DUMONT LABORATORIES
UPPER MONTCLAIR, N. J.

No Need of Air or Electric Power . . . .

and BETTER control than usually obtained with auxiliary power



This radically new type of temperature controller draws power from the very steam which it controls. Result: a 1°F. change at bulb suffices to effect full travel of valve (ordinary self-acting regulators require 10° to 20°). For all steam-heated processes the new Johnson Regulator is *the most sensitive control instrument* on the market.

Forget your ideas based on self-acting regulators you've known, and send for data on this modern type.

Emil T. Johnson Regulator Co.
6435 N. Talman Ave. Chicago, Ill.

DESIGN and USE OF INSTRUMENTS AND ACCURATE MECHANISM

by

Thomas North Whitehead

Lately Scientific Officer, British Admiralty; Assistant Prof., Harvard School of Business

". . . Beautifully written text . . . daring originality amounting to nothing less than a new philosophy of instrument design and construction . . . these definitions (introductory chapter) reveal a brilliant, vigorous, unfettered mind . . . (The) last chapter, too, would entitle Whitehead to lasting fame, but then, so would the intervening chapters . . ."—INSTRUMENTS

"Although written primarily for designers of instruments and those who use them, the subject matter transcends these limits."—MACHINE DESIGN

at all bookstores **Macmillan**

$3.50

galvanometer pointer 17 to touch lightly contact 18 (or 19), current from battery 20 (or 24) flows through galvanometer coil 11 in a sense to accentuate its deflection and intensify the contact pressure, thereby decreasing the contact resistance and further increasing the contact pressure until magnet M2 (or M1) is sufficiently energized to operate relay X with mercury switches 21 and 27 (or relay Y with switches 25 and 28). In each relay, one of the mercury switches is in circuit with reversing motor M which drives helical slide wire 2 in a direction to restore balance in the measuring circuit,

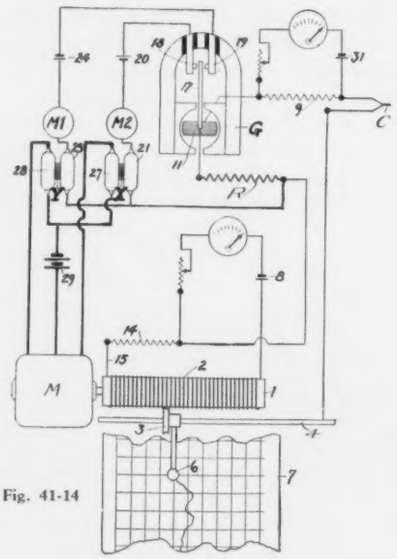


Fig. 41-14

and the other in circuit with the relay magnet. As the relay operates to close the motor circuit it also opens its own magnet circuit, which results in a step-by-step or "tapping" action of the balancing mechanism, ceasing when, at the completion of any step, pointer 17 touches neither of the contacts 18 and 19.

As manufactured, the Uehling self-balancing potentiometer comprises a galvanometer-and-relay assembly unit and a separate recording instrument which may be located remotely and which contains only the elements shown at the bottom of Fig. 41-14. This separate instrument is supplied in various forms: strip-chart recorder, round chart recorder combined with 24-inch illuminated scale indicator, etc. One galvanometer-and-relay unit may serve a plurality of recorders—generally up to six.

INSTRUMENTS BOOK SHELF

The Practice of Absorption Spectrophotometry with Hilger Instruments. By F. Twyman and C. B. Allsopp. Second Edition. Adam Hilger Ltd., London, 1934. Cloth, 6¼ x 9¾ inches, 140 pages. Price 12s 6d.

It is unfortunate that this excellent handbook could not have been expanded slightly so as to include the broader subject of the Practice of Spectrophotometry without regard to the maker of the instruments used. In spite of this limitation the book will be extremely useful to workers in this field and for those who wish to have a general understanding of the methods and interpretation of spectrophotometric data. The book is divided in three parts: the interpretation and application of absorption spectra data, the technique of observation and recording, and a general summary and appendices covering special methods and applications. The book is particularly useful in the presentation of various systems of nomenclature and the recording of spectrophotometric data. Wallace R. Brode (7.5)-B-

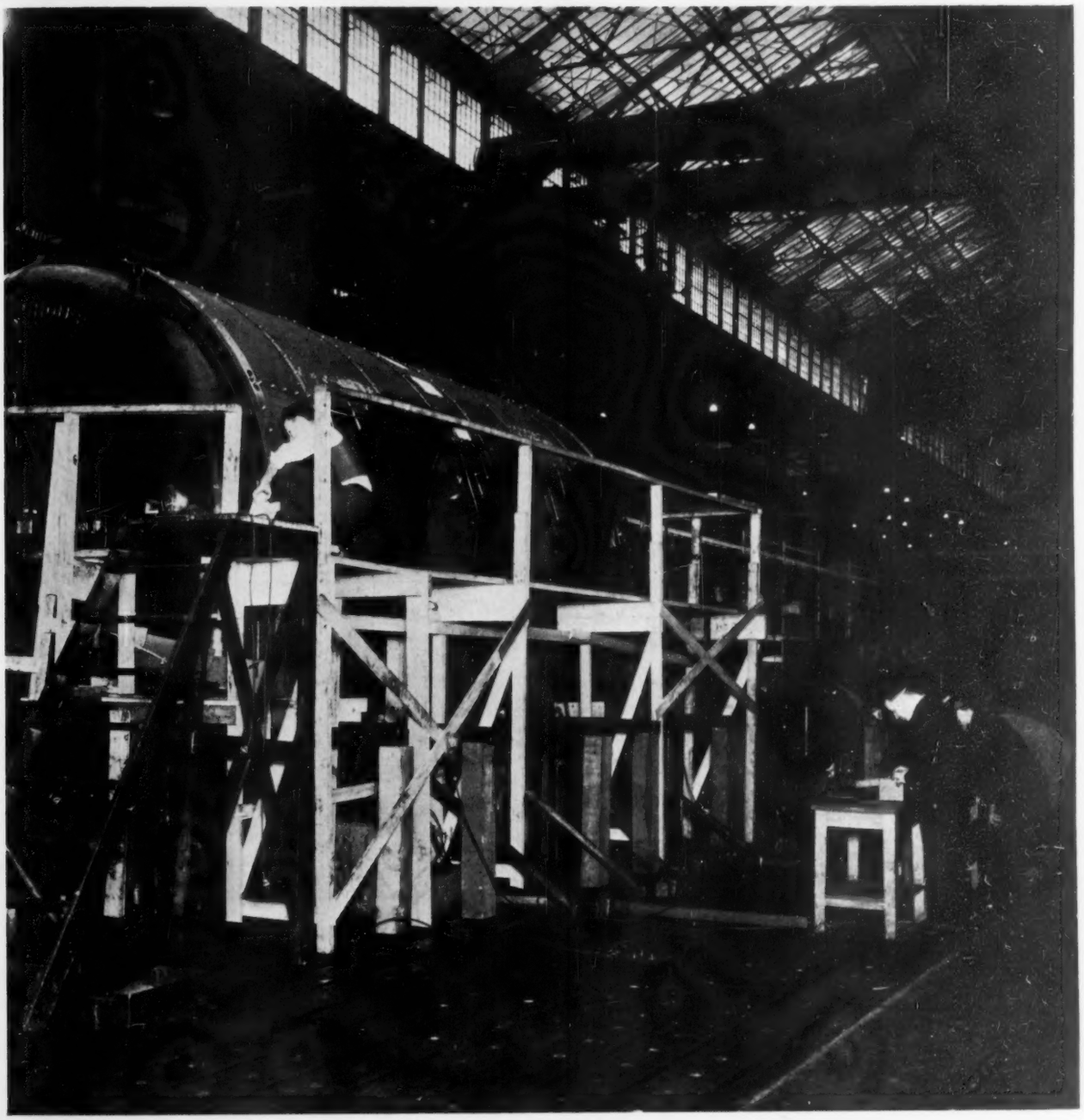
Dictionary for Photogrammetry (Mehrsprachiges Wörterbuch für Photogrammetrie). Published by the Deutsche Gesellschaft für Photogrammetrie, Berlin, 1934. Paper, 128 pages, 7 x 10 inches. Price 8 RM.

The dictionary is in five languages: English, French, German, Italian and Spanish. It contains 1850 expressions in this field. These are arranged alphabetically in German with the translations in the other languages. The expressions are numbered. In the appendix there are the lists of English, French, Italian and Spanish words with references to the corresponding German words. Richard Rimbach (7.6)-B-

Trouble-Shooting for Radio Service Men. A. A. Gheradi & B. M. Freed. Radio & Technical Publishing Co., New York, 1934. Cardboard, 5 x 6¼ inches. 25 cents.

Though consisting of cardboard "pages" this is not a "book" but an ingenious gadget to assist servicemen in trouble-shooting. According to the symptom detected by the serviceman, the gadget lists, under eight sources, 275 possible troubles in the receiver. Six general types of symptoms are dealt with: Hum; Weak; Noisy; Inoperative (no signals); Intermittent Reception; Fading; Oscillation and Distortion. Trouble sources are classified under: Power Unit; Receiver Circuits Proper; Tubes; Reproducer; Antenna Ground; "A" Battery (if used); "B" Battery (if used); and General. (5.1)-B-

INSPECTION and TESTING



Adjusting Watthour Meters for Current Transformer Errors

By H. W. RICHARDSON

SELECTION of current transformers having the proper rating for use in a metering job installation presents an engineering problem having the following factors: (*a*) The average ampere load; (*b*) The maximum ampere load; (*c*) The probable short circuit current; (*d*) The probable load fluctuation throughout the day. It should also be remembered that a current transformer has a limited overload rating.

Current transformers are now available with automatic compensation for both ratio and phase angle errors, the compensation varying with the ampere load; and the degree of compensation (partial or full) varying with the quality of the transformer. The reluctance of the magnetic circuit of the transformer core changes automatically with the current.

Watthour meters are now available specially designed for use with current transformers and are designated as "transformer-rated meters." With such a meter and a compensated current transformer, a variation of not more than 1 or 1.5% in ratio and 1 degree or 30 minutes in phase angle throughout the entire range of 10 to 100% load may be expected.

Current transformers generally used with watthour meters (or indicating wattmeters) possess ratio and phase angle errors. Individual transformers of a given design may be expected to agree within $\pm 0.5\%$ in ratio and within 15 minutes in phase angle with the average accuracy for that design.

The reader should differentiate between the "true ratio" and "rated ratio" of current transformers. The "true ratio" is determined by actual tests. Most current transformers are designed to produce 5 amperes in the secondary when full rated current flows in the primary. Hence, with a transformer rated 40 amperes (primary) divided by 5 amperes (secondary) the rated (nameplate) ratio should be 8 to 1. However, in the example being discussed, it was found after testing the transformer that 39.9 amperes in the primary would produce 5 amperes in the secondary; thus the true ratio is $39.9 \div 5 = 7.98$.

If now we divide the true ratio by the rated ratio, in this case, $7.98 \div 8 = 99.75$. This figure 99.75 is usually referred to as the ratio error of the transformer in accuracy curves furnished by the manufacturer. In other words if the factor obtained by dividing the true ratio by the rated ratio is *less* than 100, it means that the secondary current is *more* than the amount which is represented by the name plate ratio, and vice versa.

In order to illustrate the application of this ratio to the calibration of watthour meters, and in order to magnify the errors, a special bushing type of current transformer has been selected. (Ordinarily, such a transformer would not be used with a watthour meter.)

Columns A and B in Table I show the true ratio at the various percentage ampere loads; and Column C shows the errors which would be produced in the registration of the watthour meter.

The plus and minus signs in Column C mean that the percent error must be added to or subtracted from the

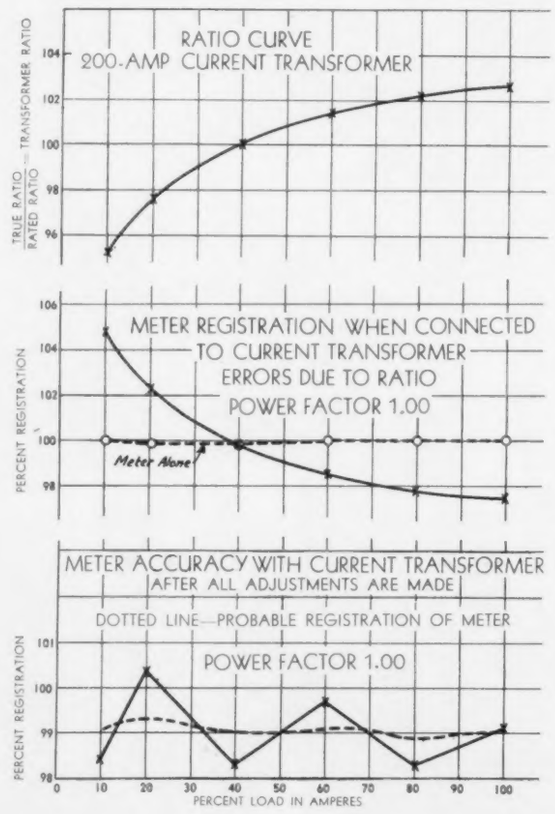


TABLE I—RECAPITULATION—POWER FACTOR 1.00

A	B	C	D	E	F	G	H
Percent Ampere Load	Current Transformer True Ratio	Percent Error	Meter Accuracy	Meter with Transformer Ratio Errors	Meter After Adjusting Magnets	Meter After Adjusting Light Load	Meter After Adjusting Lag Device
10	95.2	+4.8	100.0	104.8	107.4	98.4	98.4
20	97.6	+2.4	99.9	102.3	104.9	100.4	100.4
40	100.0	0.0	99.9	99.9	102.5	98.3	98.3
60	101.4	—1.4	100.0	98.6	101.2	99.7	99.7
80	102.2	—2.2	100.0	97.8	100.4	98.3	98.3
100	102.6	—2.6	100.0	97.4	100.0	99.1	99.1

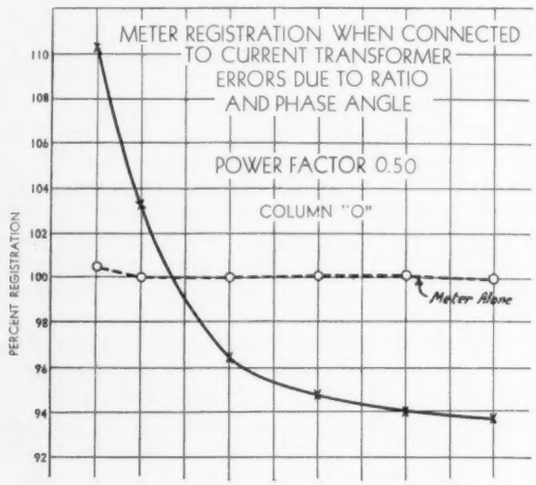
registration of the meter to obtain the correct total registration with the transformer.

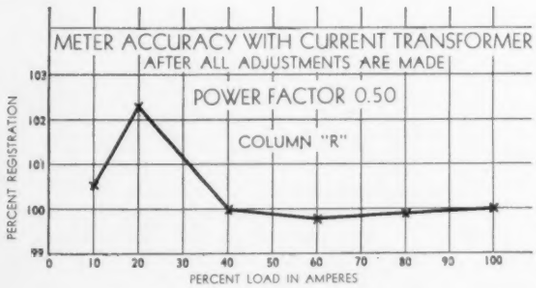
Connecting the five-ampere single-phase meter, whose characteristics are shown in Column D, to the transformer having a ratio curve as in Column B, the resultant registration is shown in Column E.

The effect of the phase angle of the transformer is negligible at unity power factor but is evident in inductive loads. Table II shows the phase angle (Column J) and errors (Column L) at various loads.

It is well at this point to mention that all phase displacements which tend to *increase* the reading of the meter are considered positive and all that tend to *decrease* the reading are negative.* By referring to Table II it will be noted that some of the phase angle errors are positive others negative. This means that on a lagging power factor where the error is positive the phase angle of the transformer has the same effect as if the meter was measuring the energy at a load power factor higher than the actual value, and when the phase angle is negative the meter records less than it should for the given power factor. Column O shows the effect of this measurement at 50% power factor.

*EDITOR'S NOTE. The new A.I.E.E. Standard calls leading secondary phase angle *positive* for current and voltage transformers.





Columns E and N show that the meter records slow on full load, yet his error may be compensated by readjusting the permanent magnets so as to speed up the meter disk 2.6%. This will affect the meter disk speed equally at all loads and the meter will record as shown in Columns F and P.

The light load is now too fast but it may be corrected by means of the light load device. The light load device furnishes only constant torque (at constant potential) hence its effect varies inversely with the load, that is, if we decrease the speed 10% at 10% load, the effect at 20% load will be only 5% and at full load only 1.%. Remember at power factor 50% the torque of the meter is only one half that at unity power factor, hence the effect of the light load adjustment is double what it is at unity power factor. The resultant change is shown in Columns G and Q after adjusting the light load device to slow down the speed 9%.

If a meter is used on a circuit the power factor of which is low and accuracy is desired, correction by means of the lag device is recommended. The meter is approximately 5% slow at 50% power factor, so we will speed up the meter 5% by adjusting the lag devices. This will not affect the calibration at unity power factor. The result is shown in Column R.

Often one is interested in a limited or short range of load variation in which the following points should be taken into consideration.

(*a*) What accuracy is desired, or what error will be tolerated?
(*b*) What is the volt-ampere burden of the secondary?
(*c*) What is the average load power factor?
(*d*) What is the lowest current to be measured?
(*e*) Over what range of current are measurements required?

There is a second method of securing the information outlined in the preceding part of this article. Nearly every electric utility possesses a rotating standard test meter. A single-phase 5-ampere meter may be tested and calibrated in the meter test room by taking readings at 10, 20, 40, 60, 80 and 100% loads at both unity and 50% power factors. Now connect the single-phase meter to secondary of the current transformer and the rotating standard in series with the primary of the transformer. The service meter may be now adjusted correct with the transformer. Many test meters have a 100 ampere maximum rated series coil; this should permit testing the meter with the current transformer up to 100 or 150 amperes. When making the test in this manner care should be taken to see that the volt-ampere burden on the secondary of the transformer, that is, the meter and current carrying loads on the secondary, equals approximately the volt-ampere burden which the transformer will carry when installed in service. After having ad-

(Continued on page 20)

TABLE II—RECAPITULATION—POWER FACTOR 0.50

I	J	K	L	M	N	O	P	Q	R
Percent Ampere Load	Transformer Phase Angle	60° Plus Phase Angle	Phase Angle Error	Meter Accuracy	Meter Plus Ratio Errors	Meter Plus Ratio and Ph. Angle Errors	Meter After Adjusting Magnets	Meter After Adjusting Light Load	Meter After Adjusting Lag Devices
10	+1° 39′	61° 39′	+5.0	100.5	105.3	110.3	112.9	94.9	100.5
20	+0° 18′	60° 18′	+0.9	100.0	102.4	103.3	105.9	96.9	102.3
40	—1° 9′	58° 51′	—3.5	100.0	100.0	96.5	99.1	94.6	100.0
60	—1° 18′	58° 42′	—3.9	100.1	98.7	94.8	97.4	94.4	99.8
80	—1° 15′	58° 45′	—3.8	100.1	97.9	94.1	96.7	94.5	99.9
100	—1° 12′	58° 48′	—3.6	100.0	97.4	93.8	96.4	94.6	100.0

Materials Testing Machines

An Account of Their Development, with Special Reference to the Tension-Compression-Transverse Group

By C. H. GIBBONS*

PART THREE

Another machine worthy of mention as having a single unique feature and similar to that of Fairbairn, was the 30-ton machine in Creusot, France. It employed a worm, wheel and screw for load application and to counteract strain instead of Fairbairn's nut and screw. The leverage was 17 to 1.[34]

In 1852, a 100-ton horizontal testing machine, designed by Ludwig Werder[35] and constructed by Messrs. Klett & Company, Nuremberg, was built for the Railway Commission of Bavaria.[36] This machine was unusual in that both the hydraulic ram used for load producing purposes and the lever weighing system were at one end of the testing machine, thereby simplifying the construction so that long specimens were more readily accommodated. The construction was such that despite the fact that it was of the single lever type, a ratio of 500 to 1 was attained, the short arm being of the order of 1/8" (3 mm.) in length. This high ratio rendered balancing difficult and a spirit level was used to indicate balance. In addition, direct measurement of the short lever length was so difficult that an auxiliary weighing system with a ratio of 10 to 1, in opposition to the main weighing system, provided a means of checking the main system. Strain of the specimen was counteracted by the movement of the entire weighing system since the main fulcrum of the great lever was mounted on the ram itself. This type of machine (Fig. 16) was extensively used in Germany, and the late W. C. Unwin stated (about 1888)[36] that during the past 15 years by far the larger part of all "original mechanical investigations" had been carried out on Werder type machines. Between 1852 and 1883[35] several Werder type machines were constructed and installed—one at Creusot, one at Stockholm, one at Spandau, one each in the Polytechnic Schools at Zurich, Munich, Vienna, Pest, one in the Gewerbe-Academic, Berlin, and one in the Engineering Institute in St. Petersburg. Many more have been built since 1883 and many are in use in Germany today.

An early American testing machine which merits description is that designed by Major W. Wade, U. S. A., and constructed under his supervision at the West Point Foundry about 1850 (Fig. 17). It was for use at the Pikesville, Maryland, Arsenal, primarily in the testing of cast iron and bronze for cannon. It had one unique feature; namely, the method of counteracting strain. This was essentially the same as the Werder machines in that one of the fulcra of the weighing system moved. It was arranged to test specimens in tension, in compression, in transverse bending (on 30" and 20" centers) and in torsion. The standard cast iron specimen was about 2¾" long and was turned to a diameter of approximately $1^{3}/_{16}$". For bronze and wrought iron, the specimens were 3" in length with square shoulders 1" apart and turned to a diameter of about $^{15}/_{16}$" at the middle. A wedge type extensometer was used between the shoulders to measure extension. By special arrangement and by specific construction of the test specimen, specimens up to about 16" in length could be accommodated. The weighing system consisted of two levers, one having a ratio of 20 to 1 and the main lever having a ratio of 10 to 1. Load was applied to the fulcrum of the first lever by means of a screw and gearing operated by hand. The ratio between the movement of the force at the circumference of the hand crank circle and the load on the specimen was 25,000 to 1. Just what this machine's capacity may have been is conjectural as the mechanical efficiency must have been low. The evidence of the tests, however, fail to reveal any loads much above 45,000 lbs.

*Baldwin Southwark Corp., Philadelphia, Pa.

[34] Lebasteur. Les Métaux, 1878.

[35] *Engineering*, London, Vol. 35, June 8, 1883, page 530.

[36] W. C. Unwin. The Testing of Materials of Construction, 1888.

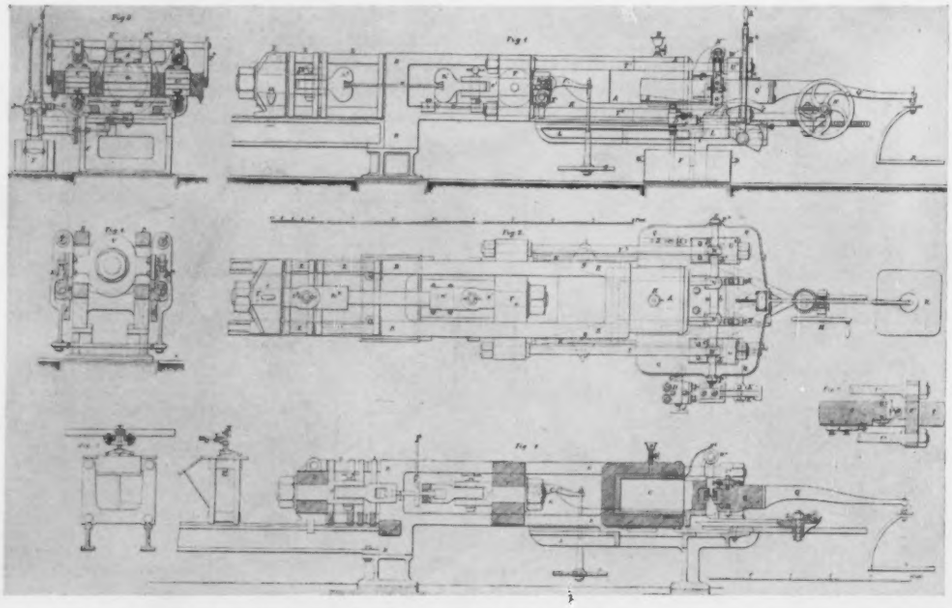


Fig. 16. A Werder Type Testing Machine. Used extensively in Germany in the latter half of the 19th century and many are still in use today.

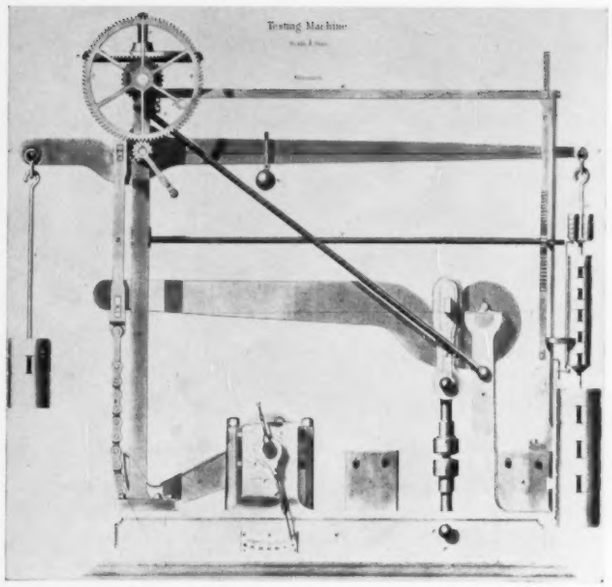


Fig. 17. The Pikesville (Maryland) Testing Machine of Major Wade, about 1850.

For torsion tests, a flat link chain was attached to the link between the first and the main levers. This operated on a lever with a circular segment at whose axis was the specimen. The torque in inch-pounds was 2½ times the load reading in pounds.[37]

Later, Greenwood and Batley, Leeds, built for Chas. Cammell and Co., Cyclops Works, Sheffield, a 50-ton testing machine which was in appearance a duplicate of Major Wade's, and as nearly as may be judged from a meagre description and a wood cut,[38] accomplished its various functions in the same ways as did Major Wade's machine.[39]

In connection with the construction in 1858 of a high pressure boiler of steel plate by Messrs. Robert Napier and Sons, Glasgow, David Kirkaldy made tests, extending from 1858 to 1861,[40] probably with the advice of Rankine. The results were published in 1862.[41] His testing machine was of the single lever[42] type without adequate means for counteracting strain.[43] The tests, however, led to the construction for him and to his design, by Greenwood and Batley, Leeds, of the famous Kirkaldy 1,000,000-lb. machine and the establishment of the first commercial testing laboratory in England at the Grove, Southwark Street, London, S. E.,[44] which was opened November 25, 1865.[45] (Formal opening January 1, 1866.)[40] This machine long held first rank as to capacity among precision testing machines in the world, although Kirkaldy, after 14 years continuous use, wrote, "I have never had occasion to go above 300 tons."[40] It accommodated compression specimens up to 21½ feet long and 32″ square,[21] and in tension to about 25 feet[45] (Fig. 18).

About the same time, the testing machine of Thomas Dunn & Co., Manchester, shown in Fig. 19, was built.[46] This machine had several unique features which give it a place in this account. As was quite common, the load was provided by a hydraulic cylinder, while it was weighed by a lever system. It had, however, a ground ram in a small cylinder which communicated with the main cylinder. The loads on this small ram were also measured by a lever system. That is, essentially, the present day Amsler scheme of load measurement without rotation of the ram. This machine also had a pressure gage probably of Bourdon tube type, although one built by Dunn for Messrs. Hingley, Worcester, in 1848, certainly did not, as Bourdon did not discover the principle of his pressure gage until about that time.[47] The other unique feature was that the gage had a maximum hand—the first reference found to this device. A 200-ton machine for 25 feet specimens was built by Dunn in 1866 for the Royal Dock Yards at Portsmouth.[48]

About the same time, Thalén and Knut Styffe, in Stockholm,[49, 50] were carrying out tests, those of Styffe being probably the most accurate up to that time. Elastic limits and Young's modulus were investigated by means of micrometer microscopes. Styffe discovered the elevation of the value of the elastic limit by over-strain. He also observed variations in tensile strength between +419° and —27° F.

In 1866 or 1867 Banks, Dinmore and Co. (Philadelphia Scale Works and later Riehle Bros. Testing Machine Co.) were scale manufacturers when a Mr. Fulton

37Major W. Wade. Report on Experiments on Metal for Cannon. *Ordnance Department, U. S. Army*, 1856, page 305, et seq., Philadelphia.
38*The Engineer*, London, Vol. 13, June 20, 1862, page 368.
39It is obvious that Messrs. Greenwoods and Batley were acquainted with the developments of Major Wade. Cf. *The Engineer*, London, Vol. 18, Oct. 28, 1864, page 269.
40W. G. Kirkaldy. Illustrations of David Kirkaldy's System of Mechanical Testing, etc., London, 1891.
41D. Kirkaldy. Experimental Inquiry into Comparative Tensile Strength and Other Properties of Wrought Iron and Steel. 1862.
42It had a lever ratio of 28 to 1 and the long lever was about 16 feet, 8½ inches in length. Its capacity is not known but the tabulations show maximum loads to have been less than 64,000 lbs.
43*Proceedings, Institution of Engineers*, Scotland, 1859.
44*Engineering*, London, Vol. 11, Feb. 24, 1871, page 147.
45*The Engineer*, London, Vol. 20, Nov. 24, 1865, page 341.
46*Engineering*, London, Vol. 1, March 30, 1866, page 198.
47*Journal, Franklin Institute*, 1852. No. 23, third series, page 102. There is a question as to the originator of the curved hollow tube type of pressure measuring device. The honor is claimed for Schintz, 1845; for Sidney Smith, 1847 and 1854; for Bourdon, 1849; and for Schaeffer, 1850. Cf. *Messtechnik*, Vol. 8, 1932, page 216.
48*Engineering*, London, Vol. 3, July 4, 1867, page 13.
49Knut Styffe. Iron and Steel. Translated by Sandberg, London, 1869.
50They used the machine of Lagerhielm, "somewhat strengthened and modified," which they increased in capacity to about 30,000 lbs.

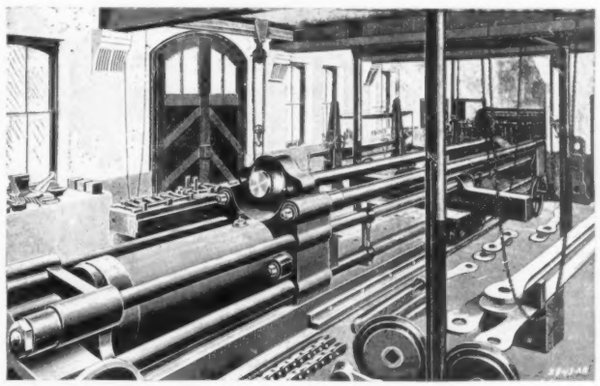


Fig. 18. The first Commercial Testing Laboratory in the world, established by Kirkaldy, London, in 1865.

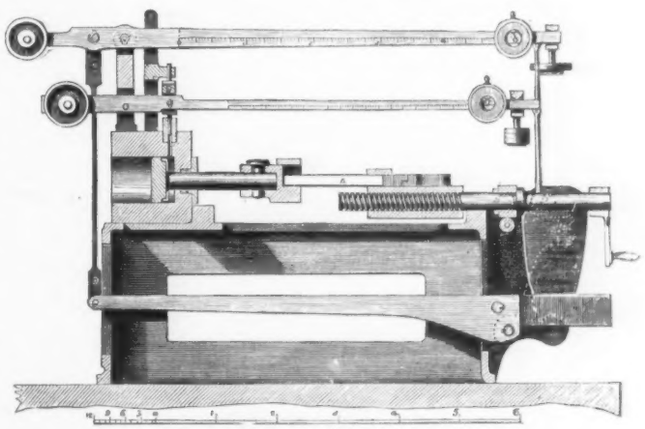


Fig. 19. The Testing Machine of Thomas Dunn & Company, Manchester, about 1865.

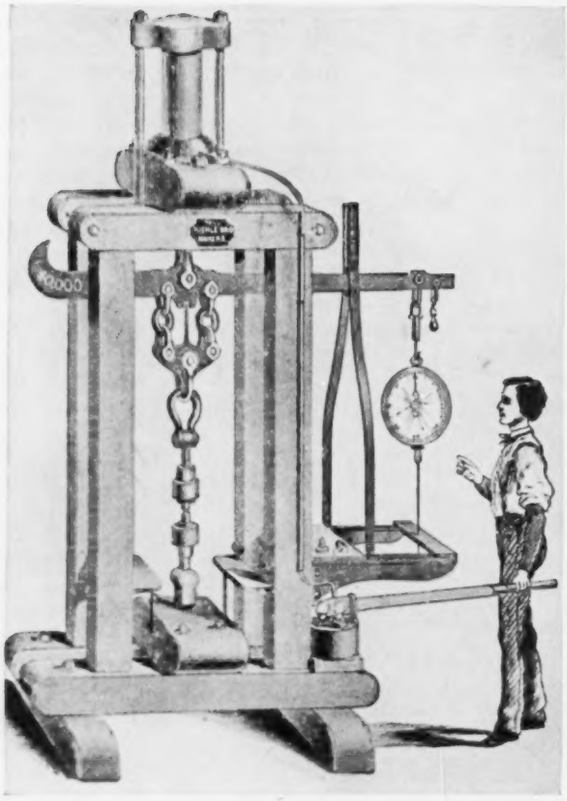


Fig. 20. An early Riehle Testing Machine, about 1867.

of S. Fulton & Company, Plymouth Foundry, Conshohocken, Pennsylvania, prevailed on them to build a machine which would test the material of the cast iron pipe which the latter was making for a certain contract with the City of Boston, Mass. This machine consisted of wooden vertical members with a wooden cross piece at the top (Fig. 20).[51] To this latter was fixed a "Justice" hydraulic jack from which was suspended a Riehle crane scale beam. To the scale beam were fastened steel clamps which formed the upper grips. The lower grips were firmly secured to the lower timber cross piece. A "Justice"[52] hand pump furnished liquid under pressure for the operation of the hydraulic jack. Its capacity was about 20,000 lbs. This was the genesis of a testing machine business which grew to large proportions and which has placed its machines in all parts of the world.

Late in this decade (1868-1870) MM. Desgoffe and Ollivier, Paris, built testing machines having two unique features, one of which later, in principle, became the distinguishing feature of a system of testing machine load indication; the other, used today in certain types of compression testing machines.[53] As may be seen from Fig. 21, the load producing and strain compensating mechanism was hydraulic. The other end of the specimen was secured to the short arm of a lever with the usual knife-edges. The long arm of a second lever in the system bore on a vulcanized rubber diaphragm, separating the lever from the fluid in the shallow auxiliary weighing cylinder. This diaphragm was secured to the cylinder at its periphery by means of a ring. The value of the load on the specimen was reduced by the lever

[51] The evidence is not conclusive that the machine shown is that described. The probability, however, is great. The cut is from a reproduction in the catalog of the Philadelphia Scale Works, dated January 4, 1872.

[52] "This was the name of the manufacturer of the jack. (He was the promoter of the William Butcher Steel Works at Nicetown, Pa., which was succeeded by the Midvale Steel Works.)" Frederick A. Riehle in Fifty Years of a Business Mans' Life, 1916.

[53] *Engineering*, London, Vol. 9, March 11, 1870, page 153.

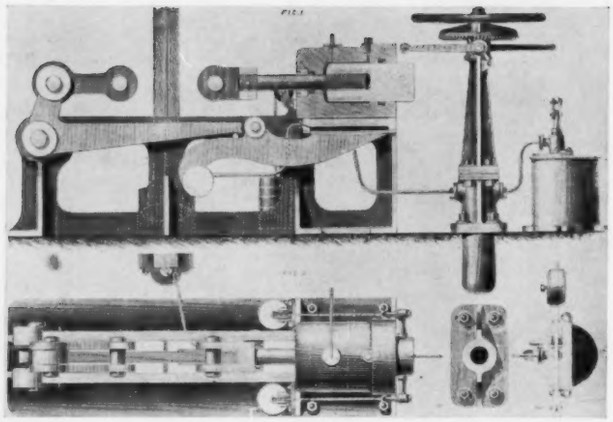


Fig. 21. The Testing Machine of M. M. Desgoffe and Ollivier, Paris, about 1869.

arrangement and, due to the construction, it was possible to measure by means of a manometer the pressure in the auxiliary cylinder, and, therefore, the load on the specimen. This gave continuous and instantaneous reading of load without the necessity of balancing a lever or beam.

The other unique feature was that the cylinder to the right of the machine was filled with liquid and a plunger forced into same. The displaced liquid entered the main cylinder under pressure, without pulsation, and produced steady and uniform motion of the ram.[53] (To be continued)

ADJUSTING WATTHOUR METERS

(Concluded from page 17)

justed the meter correct with the current transformer, take a second set of readings on the meter at 10, 20, 40, 60, 80 and 100 percent load. The difference between the first and second set of readings gives the transformer errors and these errors can be used in the future as correction factors in case the meter is tested as a secondary meter at the point of installation.

What should be done in case the meter connected to the current transformers happens to be a polyphase meter? It is quite probable that the current transformers used for each element of the polyphase meter will possess similar ratio and phase angle characteristics within close limits. The *average* of the current transformer errors may under these circumstances be used as the correction factor in calibrating the meter. Otherwise, the problem is of such complexity that it cannot be covered in an article such as this, and the reader is referred to a specialized text book such as "Electric Power Metering" by A. E. Knowlton.

AN AIR-DAMPED ACCELEROMETER

(Concluded from page 6)

respond to one-fourth wave length, or a frequency of 1 vibration per second. It can be seen from the plot that the response is not an exact reproduction of the imposed acceleration. There is a certain phase lag which depends upon the two frequencies f_1 and f_2. When necessary this phase lag can be estimated and a correction made.

In relatively slow maneuvers the first two terms of equation (1) may be neglected. In fast maneuvers, where the shape of the acceleration curve instead of merely the maximum acceleration is desired, these terms must be considered. This need is particularly true of accelerometers of type 3 and the one described by Bouny[1]. Fortunately it is possible to take account of these terms, and thereby to obtain the true value for the imposed acceleration.

Correction can also be made for the effect of accelerations parallel to the vane. This correction has been discussed in detail by Norton and Warner.[2] The air-damped accelerometer is so arranged that the acceleration parallel to the vane is small, thus making it unnecessary to make this correction except in special cases.

NEW INSTRUMENTS

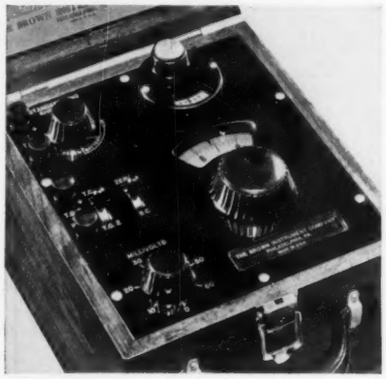
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

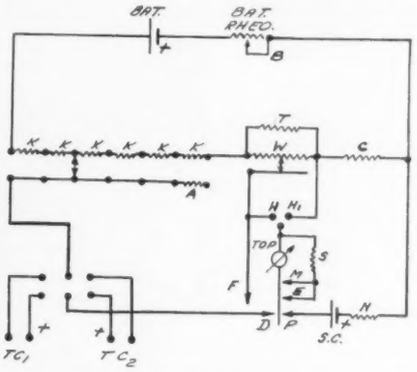
When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Portable Potentiometer

A new portable potentiometer designed to enable pyrometer users to check their potentiometers, millivoltmeters and thermocouples quickly and accurately is announced by The Brown Instrument Co. Combination of a step-switch and slide wire makes it possible

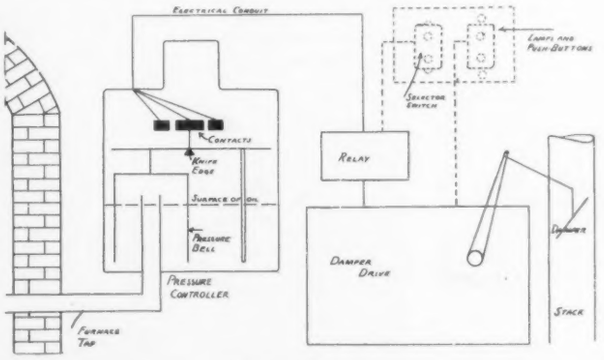




to read indicating scale to 0.01 mv. over a total range of 72 mi. This combination is equivalent to having a slide wire 109″ long. Indicating scale is 17″ long, making the smallest scale division (0.05 mv.) > 1/16″ in width. Fully-enclosed, suspension type galvanometer has short period (approx. 2 sec.) so that readings can be taken rapidly. Two sets of binding posts and a toggle switch, provided for thermocouple checking, further facilitate operation. Potentiometer circuit has been designed primarily for checking pyrometers and thermocouples. In addition, new instrument can be used as a measured source of emf. in checking recording potentiometers of the self-balancing type. Circuit draws only 3 ma. from dry cell, giving dry cell a life of several months and permitting instrument to be used for several hours on one standardization of battery current. Case is 9⅜″ wide x 10¼″ deep x 6¾″ high; weight is 12¾ lbs.

Furnace Pressure Control System

In operating open-hearth, glass tank and other types of furnaces, operator's attention is engaged by numerous factors, so that he cannot constantly regulate pressure. Leeds & Northrup Co.'s new system relieves him of this duty. It consists of a compensated inverted-bell type element with single or double limit contacts commanding a damper motor through a relay, with red and green signal lamps, etc. Pressure controller is available in either of two types: (1) single-contact, providing one rate of control response, (2) double-contact "proportional-acting" giving two rates of control response. Both types have micrometer adjustment device and normal range of +0.05 to —0.10 in. of water, variable by shifting weight on balance arm. When automatic regulation reaches either of its limits under extreme conditions, red or green lamp signals furnace operator, who then switches from automatic to manual and operates damper himself from a push-button station. Damper drives are available with output torque and other characteristics suited to application, standard motor being ⅛ h.p.; 115 or 220 volts d.c., or 110 or 220 volt 3-phase 60-cycle a.c. Controller, relay and damper drive are all in heavy dust-proof cases. Recommended installation is controller, selector switch, lamps, push-button station and relay cabinet all on one panel so located that pipe from furnace tap to controller will not accumulate water.



PYRO THE SIMPLIFIED OPTICAL PYROMETER

SELF-CONTAINED, DIRECT READING
RUGGED AND FOOL-PROOF

Unique construction enables operator to rapidly determine temperature even on minute spots, fast moving objects, or smallest streams; no correction charts, no accessories.

PYRO OPTICAL is NOW available in a NEW TYPE WITH THREE SEPARATE, DIRECT READING SCALES — the ideal instrument for universal steel mill uses, open hearths, soaking pits, rolling mills, laboratories, etc.

Stock Ranges
1400° F. to 5500° F.

Bulletins on Pyro Radiation, Immersion & Surface Pyrometers, Pyro Super-Sensitive Radiation Tubes and Rapid Recorders on Request.

THE PYROMETER INSTRUMENT CO.
103-107 LAFAYETTE ST., NEW YORK, N. Y.
GRANT BLDG., PITTSBURGH, PA.

SIZE 5" x 4⅞" x 2¾" DEEP
OVER ALL HEIGHT 3⅞

FULL SCALE 0.3 MICROAMPERE

Rawson meters are the only ones having two pivot movements whose weight is lifted from jewels when clamped for transit. Electrical clamping does not accomplish this purpose.

Dynamometer wattmeters, milliammeters and voltmeters. Also ultra-sensitive meters both for A.C. & D.C., fluxmeters, electrostatic voltmeters from full scale 120 volts to over 20,000 volts, thermocouples, earth current meters, cable testers, fluxmeters, etc.

Special Apparatus Built to Order.

RAWSON
ELECTRICAL INSTRUMENT CO.
Cambridge, Mass.

Branch: 91 Seventh Ave., New York City
Representative: E. N. Webber,
Daily News Bldg., Chicago, Ill.

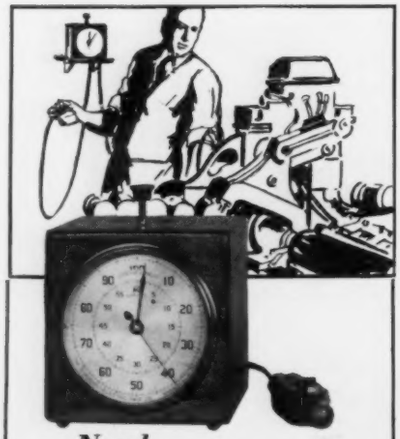
SHALLCROSS

Wheatstone Bridge

This Wheatstone Bridge, built around a highly sensitive galvanometer and Shallcross resistors, provides a simple and rugged yet accurate instrument capable of resistance measurements from 0.01 ohms to 11.1 megohms.

Send for Bulletin No. 630-H describing this instrument.

SHALLCROSS MFG. COMPANY
Electrical Measuring Instruments and Accurate Resistors
700 MAC DADE BOULEVARD
COLLINGDALE, PA.



Need

ACCURATE TIMING?

. . . here it is!

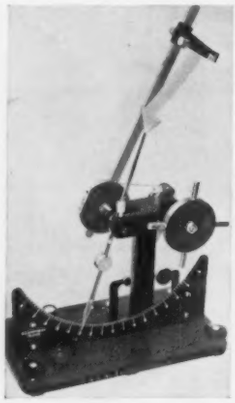
The STANDARD ELECTRIC STOP CLOCK makes every second count and counts every second into fractional units as small as 1/300th if desired. In shop, laboratory and classroom its accuracy, ruggedness and utility have made it a favorite. Handy remote control switch. Large easily read dial. Write for complete information.

The "STANDARD" ELECTRIC STOP CLOCK

THE STANDARD ELECTRIC TIME CO.
SPRINGFIELD . . MASS.
Offices in all Principal Cities

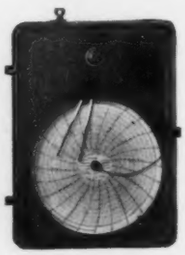
R. D. Stiffness Tester

Stiffness, softness, pliability, or "feel" of all kinds of paper from cigarette to hanging or bristol, is measured and readings expressed in milligrams on W. & L. E. Gurley's new tester. Prepared sample is clamped in a moveable arm and dragged over the top of a weighted pointer, until bending of paper releases pointer. Deflection, read on double sine scale at bottom, is the measure of stiffness. Sample-holding clamp can be raised or lowered on arm, permitting use of samples from 1" to 4½" lengths. Width may be from ½" to 2". Pointer can be loaded with weights of 5, 25 or 50 g., placed at any one of three distances below center. Clamp arm is rotated by a wire belt running from a capstan handle turned by observer. Leveling screws and a circular spirit level are provided. Readings are taken both with and against any curl on the one sample, *i.e.*, on right and left halves of scale, and averaged. Five samples, all humidified to some standard condition, should be tested to obtain an average. Mechanical errors of tester are negligible: weights are adjusted to fine tolerance; locating holes for weights and clamp are precisely spaced; scale is engine-divided; pivot bearing for pointer arm is jeweled. Instrument is made of bronze, aluminum, and stainless steel, finished in black, with chromium-plated small parts. Height, 17"; base, 6" x 10½"; weight, 13 lbs.



Improved Case for Flowmeters, etc.

Better appearance, utility and convenience of orifice measurement and flow control instruments is announced by American Meter Co. in new "Type W" case, now standard for company's line of flow meters, rate-volume controllers, liquid level indicators and controllers. Simple lines; velvet black finish; body and door cast of aluminum alloy; hinges and hinge pins of corrosion resistant alloy; sponge rubber gasket secured in a recess, etc. Chart dial size is such that pressure-spring, stuffing box and other working parts are visible when door is open. For flush mounting a flange is cast integral with case, door being hinged to flange. For flow control instruments, door is provided with two additional round windows for air supply and controlled-air gages and all air connections are behind panel board, being made to flanges secured to sides or back of case.



Liquid Fuel Flowmeters

For indicating instantaneous rate of flow of transparent liquids, three new meters have been brought out by the Eclipse Aviation Corp. *Principle* is that of the "area meter" whereby the loss of head remains constant and the orifice area varies with the rate of flow. *Construction*: A tapered rod is concentrically positioned in a vertical cylindrical glass tube so that the annular area is least at the bottom and greatest at the top. A colored annular piston or float occupies a portion of the area between tube and rod, leaving for passage of fluid the difference of areas—relatively small when float is at bottom and relatively large when float is at top. Position of float consequently indicates flow rate through tube. *Scales* at sides of tube may

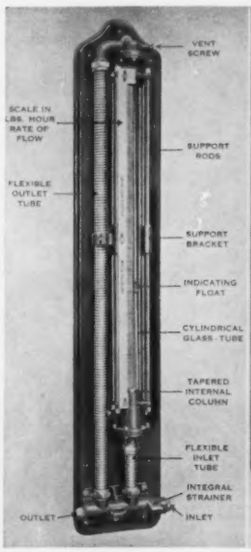


Fig. 1

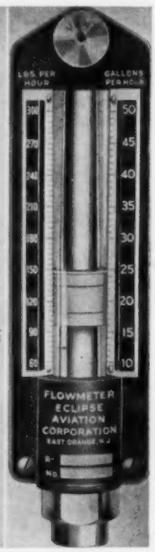


Fig. 2

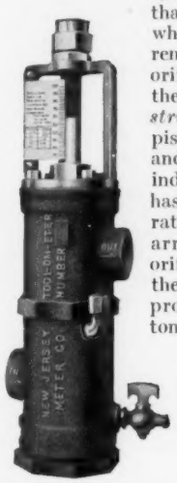
be calibrated volumetrically or gravimetrically, when density and viscosity of metered liquid are known. *Models* include one for engine test stand, Fig. 1 (greatly reduced) with a range of 50 to 600 lbs./hr.; one for instrument panel, Fig. 2 (approx. half actual size) with two scales reading 10-50 gals./hr. and 60-300 lbs./hr. respectively; and also an illuminated remote-reading model scaled 160-400 lbs./hr. *Principal Applications*: Automotive and aircraft engines, on test stand or in actual service.

Solenoid Valve

For control of refrigerant lines in air conditioning and general refrigeration work the Detroit Lubricator Co. has redesigned its 683-R Solenoid Valve. Developments have resulted in greater capacity by providing larger port orifices; greater "lifting power," and minimizing a.c. hum. Improved No. 683-R Solenoid Valve has been especially designed for liquid line control of methyl chloride, sulphur dioxide or freon. It can also be used on suction lines where its capacity permits. Closing circuit energizes coil, lifts plunger and opens valve. Breaking circuit closes valve. All coils are vacuum impregnated. Valve consumes approximately 13 watts and will operate continuously without over-heating.

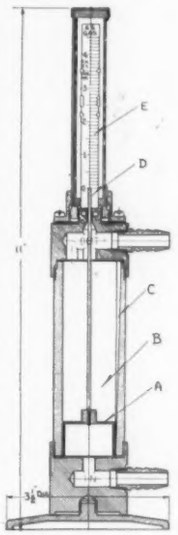
Compressed Air Flowmeter

For indicating instantaneous rate of flow of compressed air, a new expanded-scale "Tool-om-eter" designated as "4-40" has been brought out by the New Jersey Meter Co. *Principle* is that of the "area meter" whereby the loss of head remains constant and the orifice area varies with the rate of flow. *Construction*: A weighted piston is free to move up and down a vertical cylinder the wall of which has a number of accurately reamed holes so arranged that the total orifice area exposed as the piston moves up is proportional to the piston travel. The piston rod extends above into a glass tube and serves as an indicator in conjunction with a scale next to the glass tube. The rod extends down into a dashpot which damps out oscillations when fluctuating air flow is being measured. *Scale* of new model is graduated from 4 to 40 ft.^{3}/min. of free air at 80 lbs./in.^{2} pressure, is stamped with a table of factors for other pressures, and can be read to nearest 0.1 ft.^{3}/min. New model is thus a smaller-capacity meter than the standard "Tool-om-eter." *Principal Applications*: Small pneumatic hammers, paint sprayers, small drills and grinders, etc.



Gas Flowmeter

For indicating instantaneous rate of flow of illuminating and fuel gas, a new small-capacity meter designated as the "Emco Flow Indicating Meter" has been brought out by the Pittsburgh Equitable Meter Co. *Principle* is that of the "area meter" whereby the loss of head remains constant and the orifice area varies with the rate of flow. *Construction*: Aluminum piston *A*, skirted for proper guiding, is free to move up and down vertical cylinder *B*, the wall of which has slot *C* which tapers from zero depth at bottom of cylinder to about 1/8" depth at top. Orifice area formed by section of slot is thus proportional to piston travel. Piston rod *D* extends above into a glass tube and serves as an indicator in conjunction with scale *E* next to the glass tube. *Scale* is graduated from 0 to 5 ft.^{3}/hr. of gas of a given specific gravity at a given pressure. Factors for other conditions can readily be applied by user. *Principal Applications*: Adjustment of gas refrigerators, pilot lights, studying leakage, etc.



Schopper
Precision Testers
for METALS, PAPER, PLASTICS, RUBBER, TEXTILES, WIRE

TENSILE TESTERS
25,000 lb. down to the one hundredth part of 1/32 ounce

BENDING TESTERS
Angles 105° to 1°. Loads 100 lb. to ¼ oz. Plots angles with load.

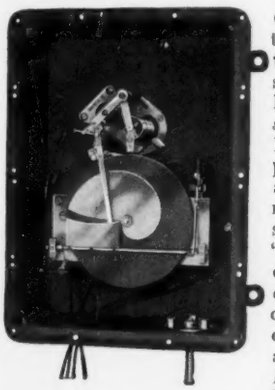
IMPACT TESTERS
ALL SYSTEMS, 120 ft.-lb. down to the one hundredth part of a 1/3 ft.-lb.

Write for Catalogues

TESTING MACHINES, Inc.
460 W. 34th STREET, NEW YORK

Re-designed "Metameter" Telemetering System

A completely new transmitter (illustrated) housed in standard instrument type case is most apparent improvement in new model "Metameter" announced by The Bristol Co. Original two-wire system was described at length in *Instruments*, Feb. 1934, page 36; and a technical description of "Chronoflo" duration-of-contact principle employed therein appeared in *Instruments*, Vol. 5, Oct. 1932, page 244. Another improvement announced is the possibility of operating two independent "Metameter" systems, each having its own transmitter and receiver, over one simple two-conductor circuit. This has been made possible by the invention of a radically new type of auxiliary relay. Even without this relay, however, one transmitter can operate a number of receivers. Standard period of cam rotation is 15 sec., which relatively rapid cycle is made possible without impairment of accuracy, by reason of new scroll cam having its leading edge forming the arc of a circle of same radius as length of pointer of primary measuring element, and its trailing edge properly formed to assure linear relation of pointer deflection to duration of impulse. Pen mechanism in receiver receives its impulses alternately from opposite directions, so that transmitting and receiving units need not be operated in absolute synchronism. System can therefore be operated successfully from independent power sources which are not of the same nominal frequency. No advantage described in previous *Instruments* articles has been sacrificed in new model.



Single-hole-mounting Switch

For use where space is a factor and where comparatively high rating and long life are important, as on electric tools, heating devices and other small but heavy-duty appliances. Developed by Merchandizing Dep't of General Electric Co. Available for single-pole, double-pole, and 3-way operation; rated 6 amp. 250 volts, and 12 amp. 125 volts. Totally enclosed in Textolite. Listed by Underwriters' Laboratories. Lock nuts or knurled rings supplied for panel mounting. 1½" long, ⅞" wide, 15/16" deep, therefore adaptable for gang mounting. Action is of wiping contact type.

WILBIN
introduces
SOMETHING NEW
in
TEMPERATURE CONTROL

This powerful electro-hydraulic VALVE ACTUATOR makes possible accurate temperature control under difficult conditions. Single seated valves are used, guaranteeing tight shut-off on "no-load." Six throttling positions. Speed of valve action and sensitivity of thermostat are adjustable by the user. You synchronize the control with the heat cycle.

WILBIN INSTRUMENT CORP.
183 Madison Ave., New York

MANUFACTURERS' NEW LITERATURE

In this department we list each month the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

C1 **Ohmite News.** The November issue of this house organ has an interesting note on the controversy as to the birthday of Georg Simon Ohm. Ohmite Manufacturing Co., 636 N. Albany Ave., Chicago, Ill.

C2 **Metameter for Telemetering.** Bulletin No. 424 describes the Metameter, which makes possible the control of temperatures, pressures, levels, and other process conditions at any distance from a few feet to several thousand miles. Bristol Co., Waterbury, Conn.

C3 **Bakelite Synthetic Resin Finishes.** A new booklet, "Integrity of Finishes" emphasizes the qualities and characteristics of Bakelite synthetic resins which impart integrity to a paint product: resistance to sunlight and weathering, moisture resistance, chemical resistance, elasticity and its retention, and toughness. Bakelite Corp., Bound Brook, N. J.

C4 **Portable Semi-Potentiometer.** Description of a semi-potentiometer with a zero resistance feature for current measurements appears in a new house organ called "Electrical Measurements," issued by the Sensitive Research Instrument Corp., 4545 Bronx Blvd., New York, N. Y.

C5 **Liquid Level Controls.** Bulletin No. 50A illustrates and describes the S & J Liquid Level Controls—Level Indicator and Electrical Signals. Shand & Jurs Co., Berkeley, Calif.

C6 **Electrical Instruments.** Catalog C covers communications equipment, laboratory standards, production test apparatus and service test apparatus. Egert Engineering, Inc., 179 Varick St., New York, N. Y.

C7 **Quinhydrone pH Meter.** Bulletin gives description and instructions for use. Working range 1.0 pH to full limit of quinhydrone method. Direct reading in pH units from 1.0 to 7.6. Accuracy 0.05 pH. E. H. Sargent & Co., 155 East Superior St., Chicago, Ill.

INVENTORS RESEARCH INSTITUTE

WASHINGTON, D. C.

Founded For Service To Inventors

Protection: Assistance in immediate protection and patent procedure.

Development: Patentability, patent searches, assistance in technical details.

Sale: Listing, locating purchasers and negotiating contracts.

All on an economical basis. A complete description of the Institute, and its purposes, will be furnished on request.

Inventors Research Institute
737 Thirteenth Street, N. W.
Washington, D. C.

I wish to apply for membership. Dues for one year, amounting to $2.00, are enclosed.

Send me the checked items:

- ☐ Free record form of invention.
- ☐ Free outline of procedure in applying for a patent.
- ☐ Free listing of my invention, described in letter.
- ☐ Free estimate of costs of other services described in letter.

Name.....

Address.....

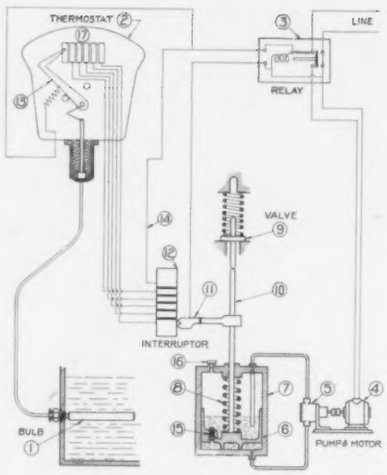


Fig. 1

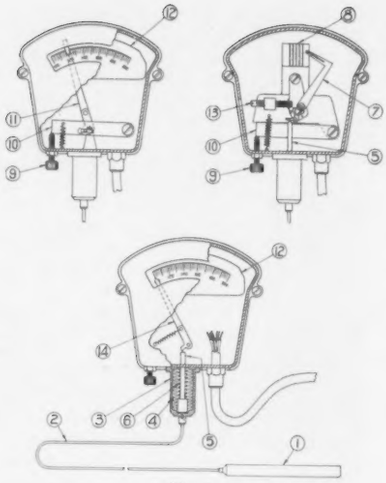


Fig. 2

Electro-hydraulic Temperature Regulator

Brought out by Wilbin Instrument Co., this temperature control system is said to be basically new and entirely different from present types. Thermal system employs liquid expansion principle. Motive power to operate single seated valves (from ¼" to 16") is derived from hydraulic pressure, generated by a standard motor-driven impeller pump. Valves return automatically to position when current fails. Sensitivity is adjustable so system can be synchronized with the heat cycle to be controlled. Available to regulate flow of steam, oil, gas, water or brine (any pressure) to maintain desired temperature from —40°F. to 950°F.

Fig. 1 shows system as a whole. When current is switched on, relay 3 is energized and closes circuit to motor 4, starting oil pump 5. This builds up oil pressure under piston 6 in cylinder 7. When sufficient pressure is built up to overcome tension of spring 8, valve 9 is opened by the rising piston 6. Attached to control plunger 10 is contact arm 11 which travels with piston and glides over contact blocks 12. Assuming the controlled liquid to be cold, contact arm 13 in thermostat 2 will be below the lowest contact in thermostat. Current will not be interrupted and valve will open wide. At top of stroke, arm 11 will close the circuit 14, thus de-energizing relay 3 and stopping motor 4. Immediately, oil pressure below piston 6 will be dissipated through adjustable leak 15 and vent 16. Valve will begin to close. However, assuming controlled liquid to be still cold, downward motion of spindle will stop when contact arm 11 opens circuit 14. Motor will start, again opening valve wide. It will oscillate in this manner at open position until heated liquid approaches the controlling point. The magnitude of this oscillation is said to be only a small fraction of valve stroke. In thermostat 2 are five contacts 17. The temperature interval is adjustable by user; all five can be covered by a temperature change of 1°F. where desired. When contact arm 13 closes lowest of contacts, contactor 11 will short-circuit relay 3, motor 4 will remain stopped and valve will move slightly toward closed position. It will now oscillate at this throttling point, until next higher contact in the thermostat is closed, and so on until valve is tightly closed. As the liquid cools, the reverse of the above cycle is begun.

Fig. 2 shows construction of thermostat: Increased temperature at bulb 1 increases liquid pressure in chamber 3, compressing bellows 4 and moving plunger 5 upward against loading spring 6. Plunger 5 actuates contact arm 7 which glides over contact blocks 8. By turning set screw 9, arm 10 is raised or lowered, thus varying point at which plunger 5 will engage contact mechanism which moves contactor 7. Arm 10 also actuates pointer 11, which shows the set temperature. By turning screw 13, contact arm mechanism is moved closer to or farther away from point of contact of plunger 5. This decreases or increases magnification of plunger movement, thereby adjusting sensitivity. An independent dial thermometer is built into same case with the control mechanism: separate pointer 14 indicates temperature at bulb 1. Its movement is not interfered with by the control mechanism.

"Numerals in Colors" for Multiple-Point Recording

Reading of multiple-point instrument records is facilitated by a new system of "numerals in colors" introduced by Leeds & Northrup Co. Each thermocouple, resistance thermometer bulb or other primary element is identified on the chart by a numeral, and each numeral distinguished from the others by a color. Colors are: black, green, red, violet, yellow and blue. This marking system can be specified on Micromax strip-chart recorders for 2, 3, 4 or 6 points. The printwheel on these recorders has a separate inking pad for each point to be recorded.

Portable Radium Detector

For locating lost radium preparations in hospitals, etc., the Curtis Radium Detector brought out by the American Instrument Co. is said to have advantages over the gold leaf electroscope: it consists of a rod-like ionization chamber exploring unit carried by hand, and the boxed instrument unit carried by a shoulder strap. A 25 mg. preparation can be detected at a distance of 7.5 feet; or 10 mg. at 3 feet.

Electric Flowmeter Using Null Method

In Cochrane Corp.'s new electric flowmeter, auxiliary power operates pointer, pen and integrator, the application of this power being controlled by a sensitive relay in receiving instrument. Differential across primary element (orifice or nozzle) in the pipe line causes a float carrying a soft iron armature and resting on the mercury in a U-tube to be displaced a certain distance and this displacement is balanced electrically by shifting a similar armature in the recorder, the two armatures being surrounded by the inductance coils of an a.-c. bridge circuit. Unbalance deflects galvanometer, which through relay shifts recorder armature to restore balance. Circuits and galvanometer are so proportioned that a displacement of transmitter armature of $< 0.001''$ causes galvanometer boom to deflect and is therefore recorded, corresponding in usual installation to 0.01 of 1% change in rate of flow at mid-scale. As no current flows through galvanometer at moment of measurement, accuracy is not influenced by electrical resistance of conductors, contact resistance, length of leads, inequalities in winding, strength of magnetic field, etc. Nor does distance between receiver and transmitter affect accuracy: the two may be located miles apart. Variations in voltage and frequency ordinarily encountered in commercial practice are said to be immaterial. Power consumption is < 25 watts. Angle through which relay shaft is turned at each adjustment is in direct proportion to deflection of galvanometer boom, and hence to degree of unbalance. Long steps and rapid adjustment are thus made when circuit is greatly unbalanced; short, precise steps as balance is approached. Instrument thus follows quick changes in rate of flow without over-shooting and without error in final adjustment. Movement of relay unit shaft is transmitted to receiver armature by a cam, so shaped that the squared relation between rate of flow and pressure differential is rectified, and relay unit shaft can be geared directly to the arm, indicator pointer and integrator index, while using uniform scales for chart and indicator.

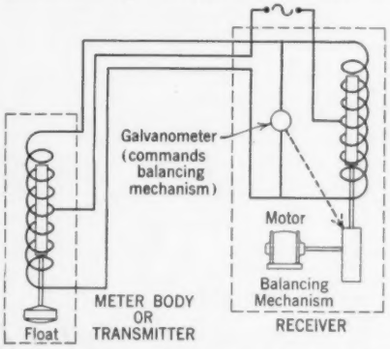


Fig. 1. Circuit diagram of electrical remote-reading system and simplified diagram of relay-type recorder.

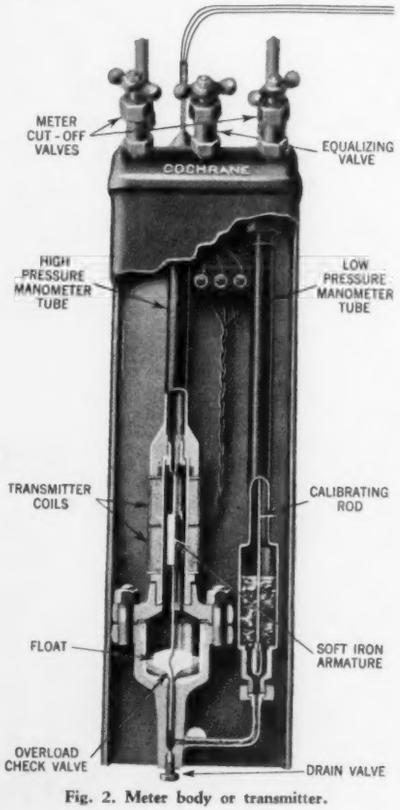


Fig. 2. Meter body or transmitter.

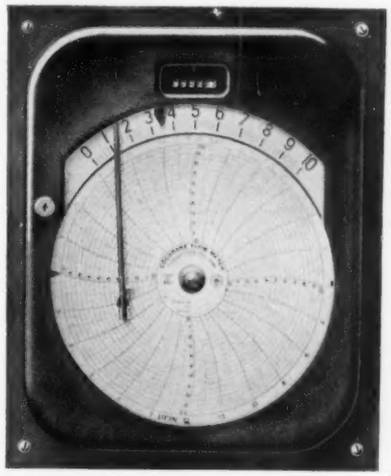


Fig. 3. Indicator-recorder-integrator.

Fig. 2 shows details of U-tube transmitter. Seven interchangeable manometer tubes of different ranges are provided: by selecting appropriate one, full scale deflection can be obtained for different operating differentials. An exact quantity of mercury in the U-tube is not necessary: a calibrating rod is built into transmitter and to check the accuracy it is necessary only to close two cut-off valves at top, open equalizing valve and raise calibrating rod from contact with mercury. Float in high-pressure chamber should then assume a position corresponding to a stated percentage of meter capacity. Should it not, calibration can at once be readjusted by turning a screw.

Fig. 3 shows outside view of receiver, wherein integration of the flow is performed at least once per minute, appropriate gear ratios being selected so that integrator multiplier will be in integral terms for different meter capacities. All the numerals on the direct-reading cyclometer-type register, except that in unity's place, move a whole space at a time, this being made possible by having ample power to drive counting train.

Surface Temperatures

Flat Stationary or Moving Curved Surfaces

The "Alnor" Combination Pyrocon

Ideal for rolls, molds, plates, platens and plastic material temperatures.

Write for bulletin.

Illinois Testing Laboratories, Inc

142 W. Austin Ave. Chicago, Illinois

WANTED

Testing Machine in first-class condition; capacity approximately 50,000 lbs. Advise where it can be inspected and lowest price for immediate delivery.

The A. P. Smith Manufacturing Co.

East Orange, New Jersey

FOR SALE—Shore Scleroscope. Practically Brand New with All Accessories. Write P. O. Box 85, Mad. Sq. Station, New York, N. Y.

C8 **Graphical Measurement of Vapor Pressure.** 8-page Bulletin No. 1 describes a vapor pressure recorder for natural gasoline plant. Industrial Engineers, 819A East 59 St., Los Angeles, Calif.

C9 **Polarizing Microscopes** is the title of a 24-page booklet discussing polarizing microscopes. Applications to several industries are covered. Bausch & Lomb Optical Co., Rochester, N. Y.

C10 **High Vacuum Pumps.** Bulletin 1385 gives complete engineering data on Gaede rotary, oil-sealed pumps, Gaede mercury diffusion all metal pumps, and all-metal oil diffusion pumps. James G. Biddle Co., 1211 Arch Street, Chicago, Ill.

C11 **Industrial Electronic Tubes.** Course 25 has been prepared for those interested in the many phases of tube development and use. It deals with the electronic tube as it has been developed and applied to industrial uses. The make-up, characteristics, and performance of the various types are treated, together with a number of typical applications illustrative of the important part they are already taking in providing new or better ways of doing things. Though prepared with the Westinghouse sales force in mind, this course, as well as others, has been made available to those outside the company. This is not a free publication, the price of this course is $2.25. Course 26 contains experiments with electronic tubes with the description of the test, a diagram of connections and the apparatus required. This is issued supplemental to Course No. 25 and is intended primarily for college work. It is, however, a practical set of experiments that can be profitably made by anyone who has access to the proper facilities for making the tests. The price of this manual is $ 65, net. These courses are issued by the Industrial Relations Department of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

C12 **Combustion Apparatus.** Leaflet describes the Chevrolet Motor combustion train for determination of carbon in iron and steel. E. H. Sargent & Co., 155 E. Superior St., Chicago, Ill.

C13 **All Wave Oscillator.** Leaflet illustrates an all wave oscillator for direct reading on fundamentals, not harmonics; full frequency coverage; absolute attenuation at highest frequencies. Egert Engineering, Inc., 179 Varick St., New York, N. Y.

C14 **Marine Radio Telephone Equipment and Radio Compass.** 20-page bulletin describes a new type of radio telephone equipment which enables captains of fishing vessels, harbor craft and yachts to have telephone service at sea comparable with that on land. A radio direction finder newly developed for use with this equipment gives bearings to within 1% accuracy at several hundred miles. Direction of incoming beam is registered directly on a scale in the pilot house. Western Electric Co., 195 Broadway, New York, N. Y.

C15 **Foxboro Recorder.** Broadside illustrates various improvements recently made in recorders for temperature, pressure, flow, humidity and liquid level. Foxboro Co., Foxboro, Mass.

C16 **Automatic Furnace Pressure Control.** Bulletin No. 842 describes this control. Installation details and mounting dimensions are given. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

C17 **Solder Pots.** Bulletin P-59, 4 pages, dimensions of various styles given. Table gives: fusion, melting points and weights of some materials. A heat absorption calculator is included. Struthers Dunn, Inc., 139 Juniper St., Philadelphia, Pa.

C18 **Air Circuit Breakers.** Catalog No. 5 gives full size drawings of Type HD, 5 to 10,000 amps.; 750 volts a.c.; 600 volts d.c. Technical details are also included. Roller-Smith Co., 233 Broadway, New York, N. Y.

C19 **Piezo-electric Tweeter.** Leaflet gives information on the type T-51 high frequency speaker of the Brush Development Co., E 40th & Perkins Ave., Cleveland, Ohio.

C20 **Insulation Testing Equipment.** Bulletin 934, 12-page bulletin on following instruments: Dielectric strength test sets, insulation resistance meter, constant temperature cabinet, humidity control apparatus and dielectric constant and power factor equipment. Sound Engineering Corp., 416 North Leavitt St., Chicago, Ill.

C21 **Sand Testing Machines.** Several loose leaves (14A, 16A and 34A) describe apparatus for measuring: tensile sand strength, flowability and transverse core strength. Harry W. Dietert Co., 676 W. Grand Blvd., Detroit, Mich.

C22 **Temperature-limit Control for Open Hearth Furnace Roofs.** Application Bulletin No. 53-116, 12 pages. This control prevents a burn-out by cutting down the fuel automatically and turning it on again as soon as the roof is safe. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

C23 **Control Counter.** Leaflet illustrates control counter which can be set to any number within the capacity of the instrument so that when the desired quantity has been tallied a signal is given and a switch is thrown, which may be utilized to stop the machine or to perform desired operations. Adde & Co., Portland, Me.

C24 **Density Comparator.** Description of a new comparator is designed for accurate and rapid quantitative spectrographic analysis. Bausch & Lomb Optical Co., Rochester, N. Y.

INSTRUMENTS, 1117 Wolfendale St.
Pittsburgh, Pa.

Have me supplied with a copy of each piece of Manufacturers' Literature listed below.

.....

.....

.....

Name.....

Position.....

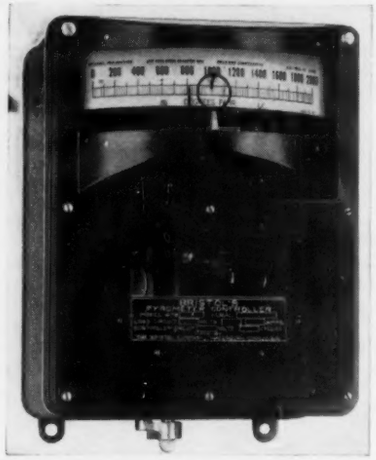
Firm.....

Street and No.....

City.....State.....

Control Pyrometer

Precision "shear-edge" action of working mechanism is operating characteristic of new pyrometer controller "Model 478," brought out by The Bristol Co. Among other features: (a) clean, non-arcing, non-oxidizing, non-corroding mercury-to-mercury electric contacts, sealed in glass; (b) no need for relays; (c) operating



mechanism always visible; (d) accessibility of Telechron motor, mercury switches and terminal block, simplifying field inspection without exposing control mechanism to dirt, fumes, or misalignment; (d) full safety features; (e) accurate control; (f) simple and rugged working parts.

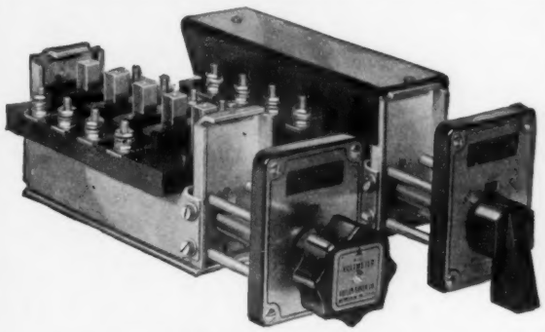
Absolute Pressure Recorder

This new instrument developed by The Bristol Co. is a recording vacuum gage compensated for changes in barometric pressure and in temperature, thereby directly recording absolute pressure without the need for applying corrections. It is equipped with two measuring elements coördinated through a special differential

transmitting linkage. One measuring element is connected to the vacuum line and the other functions in connection with the compensating features of the recorder. This instrument can be furnished for ranges as low as 25 mm. Hg. abs. or equivalent. Case is of rectangular form, wall or flush type.

Micro Oscillograph-Galvanometer

In present standard types of oscillographs, d.c. sensitivity is generally of the order of 1 mm. scale deflection for 1 to 0.1 ma. For many uses outside of power circuit analysis, higher current sensitivity seems desirable and natural frequency need not be as high as in standard commercially available types. Since higher current sensitivity is most readily accomplished by a reduction in natural frequency, the multiple-element galvanometer employed in the Heiland Research Corp.'s new oscillograph has a d.c. sensitivity of 1 mm. scale deflection for 1–5 microamps, at a natural frequency of about 200, when as many as six elements are used in a common magnetic field. With a damping of 0.7 critical, dynamic sensitivity of these oscillographs is thus only about 25% less than static sensitivity, for extraneous frequencies of the order of the natural sensitivity; it drops to about ¼ of the d.c. sensitivity for extraneous frequencies of around 400. This furnishes still sufficient sensitivity for many applications and obviates need of several stages of vacuum tube amplification. Principal claims for new oscillograph with camera are ruggedness and portability. One permanent magnet is used for six elements. Paper is driven at speed of 15-20 in./sec. and is started instantaneously by an electromagnetic clutch. Timing device contained within recorder projects lines across paper at intervals of 1/100 sec. Camera is driven by a spring motor, and all electrical operations are controlled by a 6 v. storage battery, to eliminate disturbances. However, entire unit can be furnished for a.c. operation if desired. Simultaneous visual observation and photography are provided. Fixed visual mirror may be replaced by a rotating mirror for observation of recurrent phenomena. Sensitivity of vibrators may be regulated individually on panel and readily determined and supervised by a built-in testing device. Paper is readily loaded and removed; no threading of end of paper into a second spool is necessary, and no knife for cutting the paper is required. Unit may be operated in daylight; for daylight development, however, a special attachment is required. While new instrument has been designed primarily for vibration recording in geophysical prospecting, it is adaptable to many other commercial and research uses, including strain measurements, non-destructive wire and rope tests, explosion analyses, vibration recording, ballistics, acoustics, photoelectricity, thermoelectricity, electrocardiography, etc.



ROLLER-SMITH
Type R Rotary Switches
Instrument and Control

These Switches are recommended for all instrument uses, also for use with all styles of circuit breakers and other electrically controlled apparatus. They are easy to mount; simple and rugged in construction; all parts are accessible and operation is unusually smooth and reliable.

The line is *complete*. . . Send for Catalog J-9.

ROLLER-SMITH COMPANY
Electrical Measuring and Protective Apparatus

MAIN OFFICE
2132 Woolworth Bldg., NEW YORK

WORKS
Bethlehem, Pa.

Sales agencies in principal cities in U.S.A. and Canada.

PHOTOELASTICITY POLARISCOPE

L308 Polariscope

This polariscope was designed in response to a demand for a compact and economical instrument for strain testing and qualitative photoelastic investigations and demonstrations on smaller transparent models and parts.

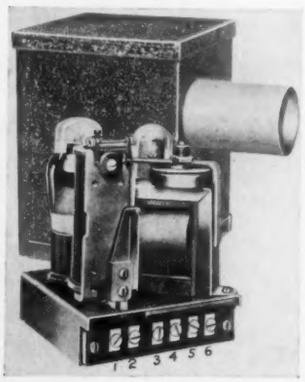
The optical parts, with the exception of the light source, are adjustably mounted on a square rod optical bench. The light source is a 6 volt concentrated filament lamp. The specimen stage with quarter waveplate and holding clip attached has a clear aperture of 2 inches. A second quarter waveplate and 10mm Nicol comprise the analyzer unit. Suitable strain free condensing and projecting lenses give a well defined and large image on the screen. A camera can be used for permanent records.

Complete description on request.

The Gaertner Scientific Corp.
1201 Wrightwood Ave. : Chicago, U. S. A.

Photoelectric Relay

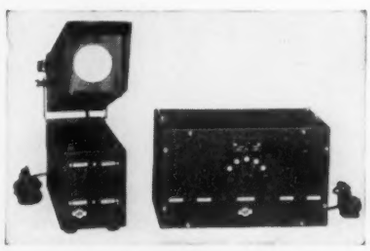
"Model A Photo Relay" just brought out by Electronic Products Co. is a compact assembly of caesium oxide phototube, potentiometer, amplifier and double contactor, housed in a 4"x4"x5" case with a removable brass beam-operation tube. Terminals 1 and 2 must be connected to 110-volt 60-cycle supply. If device to be controlled uses this supply, it is connected across 3 and either 4 or 6, depending on whether normally-open or normally-closed operation is desired. To make use of auxiliary power, controlled device and battery or other source are connected across 5 and either 4 or 6. Brass tube is removed when relay is to be used for illumination control instead of beam operation. Maximum speed of relay (in grading, counting, etc.) is 400 cycles per minute.



Cathode-ray Equipment

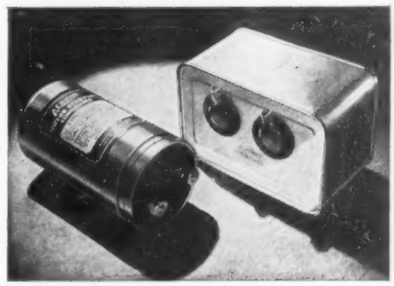
Cathode ray oscillograph and oscilloscope equipment for laboratory, production and radio applications is announced by The Clough-Brengle Co. Model UF Oscilloscope employs standard 3" cathode-ray tube, has a self-contained rectifier and filter system. Built-in 60-cycle sweep allows study of Lissajou figures for analyzing voltages and currents. Unusual mechanical features are said to be incorporated. Sensitivity is 0.31 mm./v. so that full deflection is attained on either horizontal or vertical plates with 90 volts. Intensity is sufficient for daylight observation. Photographs can be made with ordinary bellows camera. A device allows tracing curves on ordinary vellum paper.

Coils for magnetic deflection are available; also two types of linear sweep units: one providing a time axis for visual curve plotting at frequencies from 20 to 200,000 (a frequency interlock circuit eliminating drift of pattern), and one for visual plotting of i.f. response curves and other receiver alignment adjustments.



Motor Condensers

Electrolytic and oil-filled condensers for condenser-start motors, in wide variety, are announced by the Aerovox Corp. Electrolytic units are obtainable with any desired terminals in round rubber-insulated or standard cans, and in rectangular cans with or without insulating jackets, all hermetically sealed so that moisture content remains stable. Special composition spacer (Aerovox feature) protects units against surges. Internal metal parts entirely of aluminum, eliminating electro-chemical action and corrosion. Oil-filled units, intended for condenser-transformer motors and power factor correction, come in sealed round and rectangular containers, various sizes and shapes and terminal arrangements. Each unit comprises thoroughly dehydrated, oil-impregnated section in "just the right volume of oil for proper oil circulation and cooling action as section expands under load and contracts when at rest."



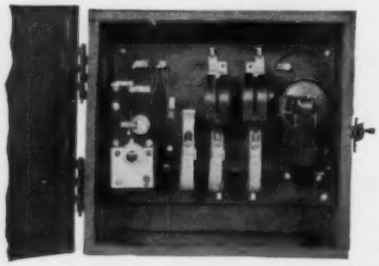
Needle Pyrometer

To serve need in some process industries for an instrument to determine more accurately the temperature of materials in plastic state during certain operations, a new needle type thermo-

electric pyrometer has been brought out by Cambridge Instrument Co. Insertion element is a thermocouple housed in a stainless steel tube similar to a hypodermic needle, providing necessary stiffness for insertion into plastic materials. A length of flexible metal protective tubing containing leads connects this element to handled indicator which has a 3" scale calibrated directly in degrees F. Standard range 50° to 400°F. *Principal Applications* are found in rubber and plastics industries. *Modifications*: various combinations of needle, surface-temperature, "mold" and other elements are announced.

Spot Welding Timer

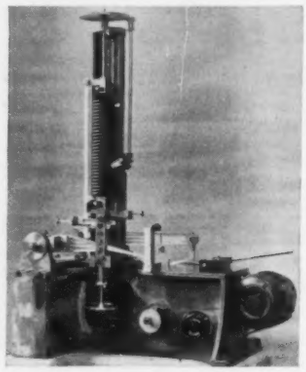
For spot and projection welders, General Electric Co.'s newly developed Type CR7993 consists of a 1-r.p.s. reversing synchronous motor operating a set of contacts which control opening and closing of a welding contactor. *Operation*: With welder idle, power is applied to the reverse winding of timer motor, causing rotation until a projection on motor shaft closes contact, hits stop, and stalls motor. This contact is in series with line contactor operating coil and initiating switch (control) on welder. When desired to make a weld, initiating switch



is closed, energizing contactor coil, closing contactor and applying power to welder. Simultaneously, power is shifted from reverse to forward winding of timer synchronous motor. During forward rotation of motor, timer contact is held closed by a permanent magnet until a second projection on motor shaft opens it and thereby opens line contactor circuit. Thus, duration of current flow at weld depends only on setting of timer, not on length of time initiating switch is closed. Opening latter switch allows timer to reset automatically for next weld. Resetting does not take place, however, until completion of a weld, even if initiating switch is closed momentarily, because an interlock on welder contactor holds circuit for duration of weld. Setting for duration of welding current is by a graduated disk associated with second projection on timer motor shaft. Range is from 1/12 sec. to 5/6 sec. in one-cycle steps (60-cycle supply). For longer times, up to 5 sec., specify a lower-speed timer motor.

Torsional Fatigue Tester

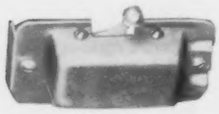
Developed by Dr. A. J. Amsler and available in U. S. through Herman H. Holz, this new machine produces torsional vibrations in a specimen between two adjustable limits which may be chosen in



such manner that specimen undergoes no permanent deformation until fatigue limit has been reached (tests being carried out well below torsional elastic limit). Test bar can be pre-loaded in one direction, and torsional vibrations superimposed, or without pre-loading it can be stressed alternately in two directions. An adjustable crank-lever deflects test bar in torsion by a definite angle. Other end of bar is connected to a stress indicator. Scale reads directly in ft.-lbs. Lower and upper limits of load can be controlled during a test. If, during a test, the specimen should undergo a permanent deformation, machine automatically maintains constant amplitude of torsional vibration. If specimen breaks, machine stops automatically. Counter registers stress-cycles to fracture. Tester has two interchangeable load ranges: 500 and 250 ft.-lbs., and operates at 1000 or 2000 cycles per minute.

Motor Starting Switch

Intended for direct mounting on built-in terminal box of standard fractional-horsepower motors; replaces standard terminal-box cover plate; requires no



soldered connections or additional wiring. Only tumbler handle extends beyond motor profile at side. Brought out by General Electric Co. Single-pole type, rated 6 amp. at 125 volts or 3 amp. at 250 volts. Applications include wood-working tools, valve grinders, cylinder reborers, drills, paint sprayers.

Indicating Pyrometer

Rugged enough for Diesel engine exhaust applications, accurate enough for applications where little space is available, Thwing Instrument Co.'s new "JR" pyrometers may be had in multiple-point model (illustrated) or in single-thermocouple model (instrument attached to three-legged aluminum bracket). Multiple-point panel measures 5¼"x8¼"; individual model fits into a 5" circle. Galvanometer is vertical, double-pivoted,

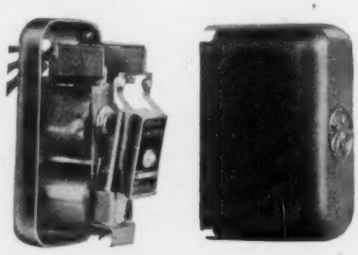
dead-beat, provided with zero adjustment. All connections to instrument and multiple switch are made at front. Switches are available with 4, 9, 12, 18, 28 or 36 points and "off." Various styles of thermocouples and fixtures available.

Differential Thermostat

Designed primarily for temperature control with room cooling apparatus during the summer, Detroit Lubricator Co.'s new "No. 691" Differential Thermostat automatically provides inside temperature control for cooling, in accordance with the A.S.H.V.E.'s "Comfort Curve." For example: when outside temperature is 95° it operates cooling unit to maintain 80°; with 85° outside it operates at approx. 77°, etc. *Principle*: two vapor-pressure thermal elements opposed to each other—one actuated by room temperature and the other by outside temperature. Quick make and break is secured by means of permanent magnets, to prevent "fluttering" contacts. Differential is approx. 1°F. Regularly furnished to make circuit on increasing temperature. Can be furnished to break circuit on increasing temperature. Can also be furnished double-throw, 3-wire. Rating: Up to 25 watts on supply up to 25 volts, a.c. or d.c. Height 5⅛", width 2¼", projection from wall 3⅛". Outside bulb ⅜" O.D., length 1¾".

Relays for Copper-oxide Rectifiers

Hesitating solenoid-control relay, Type HG-15, has been developed by General Electric Co. for use with copper-oxide-rectifier solenoid mechanisms. Relay coil operates on d-c. side of rectifier and relay contacts on the a-c. side; when so used the contacts will handle currents up to 50 amp. at 220 volts. Complete relay with its metal container weighs 2¼ lb.; is 2⅛" wide, 4⅛" high, and 2 15/16" deep.



INSTRUMENTS INDEX

Devices for Measurement, Inspection, Testing or Control

If you are unable to find what you require in this section of INSTRUMENTS, write Information Section, Instruments Publishing Company. Give complete information of requirements.

AIR METERS
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Bristol Co.
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.

ALTIMETERS
J. P. Friez & Sons, Inc.
General Electric Co.
Taylor Instrument Cos.

ALTITUDE BAROMETER
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.

AMMETERS—Indicating
General Electric Co.
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst., Corp.

Recording
Bristol Company
Brown Instrument Co.
General Electric Co.
Pioneer Instrument Co.
Roller-Smith Co.

ANEMOMETERS
Bristol Company
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.

ASPHALT TESTING APPARATUS
Taylor Instrument Cos.

ASTRONOMICAL INSTRUMENTS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

ATTENUATION NETWORKS
General Radio Company
Ward Leonard Elec. Co.

AUDIO-FREQUENCY OSCILLATORS
General Radio Company

BALANCES
Roller-Smith Co.

BALANCING MACHINES
General Electric Co.

BAROMETERS
Bristol Company
J. P. Friez & Sons, Inc.
Gaertner Scientific Corp.
Taylor Instrument Cos.

BATTERY TESTERS
Roller-Smith Co.
Weston Elec. Inst., Corp.

BEARING TESTERS
Burgess Labs., Inc., C. F.

BEATING TESTERS
Testing Machines, Inc.

BIMETAL ELEMENTS
W. M. Chace Valve Co.

BOARDS: INSTRUMENT
Bailey Meter Co.
Bristol Co.
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.

BOILER METERS
American Meter Co.
Bailey Meter Co.
George Sidney Binckley

BRAKE TESTING METERS
Rawson Elec. Inst. Co.

BRIDGES, ELECTRICAL
Capacity, Inductance, Kelvin Resistance, Temperature, Wheatstone, Percent
General Electric Co.
General Radio Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Thwing Instrument Co.

CABLE TESTERS
Rawson Elec. Inst. Co.
Roller-Smith Co.

CALORIMETERS
American Meter Co.
Gaertner Scientific Corp.

CAPACITANCE METERS
General Electric Co.
General Radio Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

CARBON DIOXIDE METERS
Brown Instrument Co.
Foxboro Co.

CATHETOMETERS
Gaertner Scientific Corp.

CHRONOGRAPHS AND CHRONOMETERS
Gaertner Scientific Corp.
General Electric Co.
General Radio Co.

CLINOMETERS

CLOCKS—Gage Board
Brown Instrument Co.
Bristol Company
Foxboro Co.
Pioneer Instrument Co.

COILS
Resistance, Inductance, Special
General Electric Co.
General Radio Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Ward Leonard Elec. Co.

COIL TESTING EQUIPMENTS
General Electric Co.
Kurman Electric Co.
Roller-Smith Co.
Thwing Instrument Co.

COLORIMETERS
Bausch & Lomb Opt. Co.
General Electric Co.
Thwing Instrument Co.

COMBUSTION CONTROL EQUIPMENT
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Pioneer Instrument Co.

COMMUNICATION MEASURING INSTRUMENTS
General Radio Company
Rawson Elec. Inst. Co.
Roller-Smith Co.
Shallcross Mfg. Co.

COMPARATORS
Gaertner Scientific Corp.
General Electric Co.

COMPASSES
Pioneer Instrument Co.
Taylor Instrument Cos.

CONDENSERS—Electrical
General Electric Co.
General Radio Co.

CONDUCTIVITY METERS
Indicating, Recording, Controlling
Rawson Elec. Inst. Co.
Roller-Smith Co.

CONTOUR MEASURING PROJECTOR

CONTROLS, AUTOMATIC
Combustion
Bailey Meter Co.
Condensation
Bristol Company
Taylor Instrument Cos.
Damper
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Feed Water
American Meter Co.
Bailey Meter Co.
Bristol Co.
Brown Instrument Co.
Foxboro Co.
Filter Rate
Bristol Company
Brown Instrument Co.
Foxboro Co.
Flow
American Meter Co.
Bailey Meter Co.
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Humidity
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Humidity & Temperature
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Wilbin Instrument Co.
Lighting
Weston Elec. Inst. Corp.
Liquid Level
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.
Taylor Instrument Cos.
Pressure & Vacuum
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Pyrometer
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.
Rate-Volume
American Meter Co.
Foxboro Co.
Refrigeration
Bristol Company
Brown Instrument Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Wilbin Instrument Co.
Specific Gravity
Bailey Meter Co.
Tachometer
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Weston Elec. Inst. Corp.
Temperature-Time
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Thermometer
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.
Thermostat
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.
Time
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Wilbin Instrument Co.
Vacuum
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Valve—Motor Operated
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Voltage A.C.
Ward Leonard Elec. Co.
Water Level
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.
Taylor Instrument Cos.

COUNTERS—Magnetic
Thwing Instrument Co.
Revolution
Bristol Company
Brown Instrument Co.
Pioneer Instrument Co.
Stroke
Bristol Company

CUBIC FOOT BOTTLES
American Meter Co.

CURRENT RECORDERS
Bristol Company
General Electric Co.
Roller-Smith Co.

CYCLE CONTROLLERS
Bristol Co.

CYCLE COUNTERS
General Radio Co.

DEMAND METERS
Gas
Foxboro Co.
Electric: Indicating, Recording, Printing
General Electric Co.

DIMMERS
Ward Leonard Elec. Co.

DIVIDING MACHINES
Gaertner Scientific Corp.

DRAFT GAGES—See Gages

DYNAMOMETERS
General Electric Co.
Rawson Elec. Inst. Co.
Weston Elec. Inst. Corp.

EARTH CURRENT METERS
Rawson Elec. Inst. Co.
Roller-Smith Co.

ELECTRIC TELEMETERS—See Remote Metering Equipment

ELECTRIC WAVE FILTER SECTIONS
General Radio Company

ELECTRONIC METERS
General Electric Co.
General Radio Co.
Rawson Elec. Inst. Co.

FAULT FINDERS
Roller-Smith Co.
Weston Elec. Inst. Corp.

FIELD RHEOSTATS
Ward Leonard Elec. Co.

FLASH & BURNING POINT TESTERS
Taylor Instrument Cos.

FLOW METERS
Indicating
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Pioneer Instrument Co.
Indicating & Recording
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Integrating & Recording
American Meter Co.

FLUE GAS ANALYZERS
Brown Instrument Co.

FLUXMETERS
Rawson Elec. Inst. Co.

FOLDING ENDURANCE TESTERS
Testing Machines, Inc.

FOOT-CANDLE METERS
Weston Elec. Inst. Corp.

FREENESS TESTERS
Testing Machines, Inc.

FREQUENCY METERS
Indicating
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.
Recording
Bristol Company
General Electric Co.
Standards
General Radio Co.

FRITTED GLASS
Fish-Schurman Corp.

FUSES
Instrument Fuses, also Auto Radio, High Voltage, Aircraft, Neon Potential Fuses and Indicators.
Send for catalog
LITTELFUSE LABORATORIES
4513 Ravenswood Ave. Chicago, Ill.

FURNACE CONTROLS
Bailey Meter Co.
Bristol Company
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Wilbin Instrument Co.

GAGES
Absolute Pressure
American Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Differential Pressure
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Draft
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Drill
Bausch & Lomb Optical Co.
Flow
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Liquid Level
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.
Taylor Instrument Cos.
Paper Thickness—Continuous
Thwing Instrument Co.
Pressure
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Pressure-Temperature
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Pressure & Vacuum
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Rain
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Recording—Distance
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.
Taylor Instrument Cos.
Strain
General Electric Co.
Vacuum
General Electric Co.
Taylor Instrument Cos.
Volume
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Wind
Bristol Company
Brown Instrument Co.
J. P. Friez & Sons, Inc.

GALVANOMETERS
American Meter Co.
Brown Instrument Co.
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Weston Elec. Inst. Corp.

Mirrors
Fish-Schurman Corp.

GAS ANALYTICAL METERS
Electrical
Brown Instrument Co.

GAS FLOW INDICATORS
American Meter Co.
George Sidney Binckley

GAS LEAK INDICATORS
Taylor Instrument Cos.

GAS-METERS
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.

Dry Test
American Meter Co.

Wet Test
American Meter Co.

GOVERNORS
Pressure
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Taylor Instrument Cos.

Pump
Bailey Meter Co.
Taylor Instrument Cos.

GRAVITOMETERS
American Meter Co.
George Sidney Binckley
Thwing Instrument Co.

GROUND DETECTORS
Roller-Smith Co.
Weston Elec. Inst. Corp.

HARDNESS TESTERS
Testing Machines, Inc.

HIGH FREQUENCY APPARATUS
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

HIGH VOLTAGE
Indicators
Roller-Smith Co.
Shallcross Mfg. Co.
Weston Elec. Inst. Corp.
Measuring Devices
General Electric Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Weston Elec. Inst. Corp.
Testing Devices
General Electric Co.

HOUR COUNTERS
Weston Elec. Inst. Corp.

HUMIDITY CONTROLLERS
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Wilbin Instrument Co.

HUMIDITY RECORDERS
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Thwing Instrument Co.

HYDROMETERS
Taylor Instrument Cos.

HYGROMETERS
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.

ILLUMINOMETERS
Weston Elec. Inst. Co.

INDICATORS—See Gages

INDUCTANCES
General Radio Co.

INSTRUMENT CALIBRATION AND REPAIRS
J. P. Friez & Sons, Inc.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

INSTRUMENT TRANSFORMERS
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.
Split Core
Roller-Smith Co.

INSULATION TESTING EQUIPMENT
General Electric Co.
Roller-Smith Co.

INTERFEROMETERS
Gaertner Scientific Corp.

KEYS AND SWITCHES
General Radio Co.

LABORATORY APPARATUS
Fish-Schurman Corp.

LABORATORY RHEOSTATS
General Radio Company
Ward Leonard Elec. Co.

LACTOMETERS
Taylor Instrument Cos.

LENSES
Bausch & Lomb Opt. Co.

LEVELS
Engineer's, Wye, Precision Prism
Taylor Instrument Cos

LIGHT SOURCES
Fish-Schurman Corp.

LIQUID LEVEL RECORDERS
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Bristol Company
Brown Instrument Co
Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co
Taylor Instrument Cos

MAGNETIC INSPECTORS
Kurman Electric Co.

MAGNETIC RELAYS
J. P. Friez & Sons, Inc.
Kurman Electric Co.
Roller-Smith Co.
Ward Leonard Elec. Co

MAGNETOMETERS
Roller-Smith Co.

MANOMETERS
Bailey Meter Co
George Sidney Binckley
Bristol Co.
Brown Instrument Co
Foxboro Co.

MASTER CLOCKS
Gaertner Scientific Corp.
General Electric Co.

MEGOHMMETERS
General Radio Co.
Roller-Smith Co.

MEGOHM VOLTMETERS
Roller-Smith Co.
Weston Elec. Inst. Corp.

MICROAMMETERS
General Electric Co.
Rawson Elec. Instru. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

MICROFARADMETERS
General Radio Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

MICROMETERS
Gaertner Scientific Corp.
Testing Machines, Inc.

MICROSCOPES
Biological
Bausch & Lomb Opt. Co.
Brinell
Gaertner Scientific Corp.
Testing Machines, Inc.
Measuring
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.
Metallographic
Bausch & Lomb Opt. Co.
Petrographical
Bausch & Lomb Opt. Co.

MICROTOMES
Bausch & Lomb Opt. Co.

MILLIAMMETERS
Bristol Company
General Electric Co.
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

MILLIVOLTMETERS
Bristol Company
Brown Instrument Co.
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Weston Elec. Inst. Corp.

MIRRORS
Bausch & Lomb Opt. Co.

MODULATION METERS
General Radio Co.
Weston Elec. Inst. Corp.

MOISTURE METERS

MOTION RECORDERS
Mechanical
Bristol Company
Foxboro Co.

MOTOR STARTERS
J. P. Friez & Sons, Inc.
Roller-Smith Co.
Ward Leonard Elec. Co.

MULTIMETERS
Rawson Elec. Inst. Co.
Shallcross Mfg. Co.

MULTIPLE PEN RECORDERS
Bristol Co.
Foxboro Co.

MULTIPLIERS
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp

NOISE MEASURING SETS
Burgess Labs., Inc., C. F.
General Radio Co.

OHMMETERS
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Weston Elec. Inst. Corp.

OIL TESTING APPARATUS
J. P. Friez & Sons, Inc.
General Electric Co.
Taylor Instrument Cos.

OPERATION RECORDERS
J. P. Friez & Sons, Inc.
Roller Smith Co.

Electrical
Bristol Company
Brown Instrument Co.
Foxboro Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.

OPTICAL FILTERS
Fish-Schurman Corp.

OPTICAL GLASS
Fish-Schurman Corp.

OPTICAL PARTS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

ORIFICE METERS

Indicating & Recording
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.

Integrating
American Meter Co.

ORIFICES, ADJUSTABLE
American Meter Co.
Bailey Meter Co.

OSCILLATORS
General Radio Co.
Weston Elec. Inst. Corp.

OSCILLOGRAPHS
General Electric Co.
General Radio Co.

Automatic
General Electric Co.

Cathode Ray
General Electric Co.
General Radio Co.

PANTOGRAPHS
Gaertner Scientific Corp.

PERISCOPES
Gaertner Scientific Corp.

PERMEAMETERS
General Electric Co.

PHOTO-ELECTRIC CELLS
General Electric Co.
Kurman Electric Co.
Weston Elec. Inst. Corp.

PHOTO-ELECTRIC COLOR ANALYZERS
General Electric Co.
Thwing Instrument Co.

PHOTO-ELECTRIC COLOR COMPARATORS
General Electric Co.
Thwing Instrument Co.

PHOTOGRAPHIC EXPOSURE METERS
Weston Elec. Inst. Corp.

PHOTOMETERS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

PHOTO-MICROGRAPHIC EQUIPMENT
Bausch & Lamb Opt. Co.

PITOT TUBE METERS
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
J.P. Friez & Sons, Inc.
Pioneer Instrument Co.

PLANIMETERS

Automatic Flow Record
Brown Instrument Co.
Foxboro Co.

Linear
Brown Instrument Co.

Radial
Bailey Meter Co.
Bristol Company
Foxboro Co.

Square Root
George Sidney Binckley
Foxboro Co.

POLARISCOPES
Gaertner Scientific Corp.

POSITION RECORDERS
Brown Instrument Co.
Bristol Company
Foxboro Co.
Taylor Instrument Cos.

POTENTIOMETERS—

Indicating
Brown Instrument Co.
General Electric Co.
Thwing Instrument Co.

Recording & Controlling
Brown Instrument Co.
Thwing Instrument Co.

POWER FACTOR METERS
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

PRESSURE RECORDERS
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

PRISMS
Gaertner Scientific Corp.

PROCESS TIMING & SIGNALING INSTRUMENTS
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

PROVERS
American Meter Co.

PSYCHROMETERS

Recording
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.

Sling
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.

PYROMETERS

Optical
Pyrometer Instrument Co.

Radiation

Indicating
Brown Instrument Co.
Pyrometer Instrument Co.
Taylor Instrument Cos.
Thwing Instrument Co.

Recording
Brown Instrument Co.
Pyrometer Instrument Co.
Taylor Instrument Cos.
Thwing Instrument Co.

Thermo-electric

Immersion
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pyrometer Instrument Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.

Indicating
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.

Recording and Controlling
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.

Surface Contact
Bristol Company
Brown Instrument Co.
Pyrometer Instrument Co.
Taylor Instrument Cos.
Thwing Instrument Co.

PYROMETER CALIBRATING SETS
Thwing Instrument Co.

RADIATION TUBES
Pyrometer Instrument Co.

RADIO FREQUENCY OSCILLATORS
General Radio Company

RADIO SET ANALYZERS
Weston Elec. Inst. Corp.

RADIO TEST PANELS
Shallcross Mfg. Co.
Weston Elec. Inst. Corp.

RADIO TUBE CHECKERS
Weston Elec. Inst. Corp.

REGULATORS—See Controls

RELAYS
J. P. Friez & Sons, Inc.
General Electric Co.
Kurman Electric Co.
Roller-Smith Co.
Ward-Leonard Elec. Co.
Weston Elec. Inst. Corp.

Light Sensitive
Burgess Labs., Inc., C. F.
Kurman Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

Vacuum Contact
Burgess Labs., Inc., C. F.

Vacuum Tube
Burgess Labs., Inc., C. F.

REMOTE METERING EQUIPMENT
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
General Electric Co.
Pioneer Instrument Co.

RESISTORS
General Radio Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Ward Leonard Elec. Co.

RETICLES
Fish-Schurman Corp.

RHEOSTATS
General Radio Company
Ward Leonard Elec. Co.

SACCHARIMETERS
Taylor Instrument Cos.

SCALES
Gaertner Scientific Corp.

Basis Weight
Testing Machines, Inc.
Thwing Instrument Co.

Differential
Thwing Instrument Co.

SHUNT METERS
Bristol Company
Roller-Smith Co.

SHUNTS
Esterline-Angus Co.
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

SIGNALING DEVICES—

Automatic
Bristol Co.
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.

SMOKE ALARMS
Weston Elec. Inst. Corp.

SPECIAL COILS
Ward Leonard Elec. Co.

SPECIAL ELECTRICAL INSTRUMENTS
Bristol Company
Brown Instrument Co.
J. P. Friez & Sons, Inc.
General Electric Co.
General Radio Co.
Kurman Electric Co.
Pioneer Instrument Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Thwing Instrument Co.
Weston Elec. Inst. Corp.

SPECIAL INSTRUMENTS
J. P. Friez & Sons, Inc.
Roller-Smith Co.
Thwing Instrument Co.

SPECTROGRAPHS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

SPECTROMETERS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

SPECTROPHOTOMETERS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

SPECTROSCOPES
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

SPEED INDICATORS See Tachometers

SPEED RECORDERS
Bristol Company
Brown Instrument Co.
J. P. Friez & Sons, Inc.
Thwing Instrument Co.

SPEED REGULATORS
Ward Leonard Elec. Co.

STANDARD CELLS
Weston Elec. Inst. Corp.

STRAIN GAGES
General Electric Co.

STROBOSCOPES
General Radio Co.

SUNSHINE RECORDERS
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.

SURGE INDICATORS & RECORDERS
General Electric Co.

SYNCHRONOSCOPES
Weston Elec. Inst. Corp.
Roller-Smith Co.

SYNCHRONIZATION FORKS

Electrical
General Radio Co.

SYNCHRONOUS MOTORS
General Electric Co.
Pioneer Instrument Co.

TACHOMETERS
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Roller-Smith Co.
Thwing Instrument Co.
Weston Elec. Inst. Corp.

TACHOSCOPES
Brown Instrument Co.

TELEMETERS—See Remote Metering

TELESCOPES
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

TENSOMETER (Huggenburger)

TESTING MACHINES
Testing Machines, Inc.
Thwing Instrument Co.

Bending
Testing Machines, Inc.

Impact
Testing Machines, Inc.

Impact (very light load)
Testing Machines, Inc.
Thwing Instrument Co.

Hardness
Testing Machines, Inc.

Magnetic
Kurman Electric Co.

Paper
Testing Machines, Inc.
Thwing Instrument Co.

Penetration
Thwing Instrument Co.

Stiffness & Bending
Testing Machines, Inc.
Thwing Instrument Co.

Stretch
Testing Machines, Inc.
Thwing Instrument Co.

Tearing
Testing Machines, Inc.
Thwing Instrument Co.

Tensile (very light load)
Testing Machines, Inc.
Thwing Instrument Co.

Universal
Testing Machines, Inc.

THERMIONIC RECTIFIERS
General Electric Co.

THERMO-JUNCTIONS (Electric)
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Wilbin Instrument Co.

THERMO-VOLTMETERS, AMMETERS
General Radio Company
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

THERMOMETERS
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
J. P. Friez & Sons, Inc.

Gas Filled
Foxboro Co.
Taylor Instrument Cos.

Mechanical
Brown Instrument Co.
Foxboro Co.

Mercurial
Bristol Company
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.

Resistance
Brown Instrument Co.
Foxboro Co.
Thwing Instrument Co.

Vapor-Tension
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

Wet & Dry Bulb
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Thwing Instrument Co.

THERMOSTATS
Bristol Company
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Wilbin Instrument Co.

THERMOSTATIC BIMETAL
W. M. Chace Valve Co.

TIME METERS
General Electric Co.
Weston Elec. Inst. Corp.

TIME OPERATION RECORDERS
Bristol Company
Foxboro Co.
J. P. Friez & Sons, Inc.

TIME RECORDERS
Bristol Company
Brown Instrument Co.
Foxboro Co.
Gaertner Scientific Corp.

TIME SWITCHES
General Electric Co.

TIMERS
Rawson Elec. Inst. Co.

TIMING DEVICES
General Electric Co.

TOTALIZING INSTRUMENTS
American Meter Co.
General Electric Co.

TOTALIZING RELAYS

Electric
General Electric Co.

TRANSFORMATION POINT RECORDERS
Brown Instrument Co.

TRANSFORMERS (Instrument)
General Electric Co.
General Radio Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

TRANSITS

Pocket
Taylor Instrument Cos.

TUNING FORKS—

Electrically Driven
Gaertner Scientific Corp.
General Electric Co.
General Radio Co.

TURBIDIMETERS
Bausch & Lomb Opt. Co.

U-TUBE MANOMETERS
Bailey Meter Co.
Brown Instrument Co.
Taylor Instrument Cos.

VACUUM RECORDERS
Bailey Meter Co.
George Sidney Binckley
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

VACUUM TUBE BRIDGES
General Radio Company

VACUUM TUBE RELAYS
Burgess Labs., Inc., C. F.

VACUUM TUBE VOLTMETERS
General Electric Co.
General Radio Co.
Rawson Elec. Inst. Co.

VALVES

Automatic Shut-Off
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.

Back Pressure
American Meter Co.

Balanced
Bailey Meter Co.
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

Blow-off
American Meter Co.

Diaphragm
Bristol Company
Foxboro Co.
Taylor Instrument Cos.

Differential
American Meter Co.

Electrically Operated
Bristol Company
Brown Instrument Co.
J. P. Friez & Sons, Inc.
General Electric Co.
Taylor Instrument Cos.
Wilbin Instrument Co.

Motor Operated
Bristol Co.
J. P. Friez & Sons, Inc.
Wilbin Instrument Co.

Pressure Relief
American Meter Co.

Proportional Air-Gas
American Meter Co.

Reducing
Bailey Meter Co.
Taylor Instrument Cos.

Regulating
American Meter Co.
Bailey Meter Co.
Bristol Co.
Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Wilbin Instrument Co.

VENTURI METERS
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.

VISCOSIMETERS
George Sidney Binckley
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.

VOLTAGE DIVIDERS
General Radio Co.
Ward Leonard Elec. Co.

VOLT-AMMETERS
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

VOLTMETERS

Electrostatic
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.

Indicating
General Electric Co.
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

Recording
Bristol Company
General Electric Co.
Roller-Smith Co.

Thermionic Rectifier
General Radio Co.

WATER METERS
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.

WATTHOUR METERS
General Electric Co.

WATTMETERS

Indicating
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

Recording
Bristol Company
General Electric Co.
Roller-Smith Co.

WAVEMETERS
General Radio Co.

X-RAY SPECTROMETERS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

pH METER, Universal
For Hydrogen, Quinhydrone, and GLASS Electrode
Write for Bulletin No. 851
AMERICAN INSTRUMENT COMPANY, INC.
774-776 Girard Street, N.W., Washington, D. C.

ADVERTISERS' INDEX

	Page
Alpha-Lux Co., Inc.	12
American Instrument Company, Inc.	A6
American Meter Company	12
Bailey Meter Company	7
Binckley, George S.	13
Bristol Company	Outside Back Cover
Brown Instrument Company	A3
Chace Valve Co., W. M.	Inside Back Cover
Commercial Engineering Laboratories	6
DuMont Labs., Allen B.	13
Foxboro Company	Inside Front Cover
Friez & Sons, Inc., Julien P.	11
Gaertner Scientific Corp.	27
General Radio Company	Inside Back Cover
Gordon Co., Claud S.	A6
Illinois Testing Laboratories	25
Inventors' Research Institute	24
Johnson Regulator Co., Emil T.	14
Littelfuse Laboratories	A5
Macmillan Company	14
Pioneer Instrument Company	10
Pyrometer Instrument Company	21
Rawson Electrical Instrument Company	21
Review of Scientific Instruments	Inside Back Cover
Roller-Smith Company	27
Shallcross Mfg. Company	22
Smith Mfg. Co., A. P.	25
Standard Electric Time Company	22
Testing Machines, Inc.	23
Trofimov School of Inventive Practice, Inc.	9
Weston Electrical Instrument Corp.	A1
Wilbin Instrument Corp.	23

RELAYS, SUPERSENSITIVE
Operate on 4 ma. at 3 v.; Break 1000 watts a-c.
AMERICAN INSTRUMENT COMPANY, INC.
774-776 Girard Street, N. W., Washington, D. C.

TESTING AND **Repairing**
Industrial Instruments all makes and kinds
CLAUD S. GORDON COMPANY
Chicago—Cleveland—Indianapolis

THE REVIEW OF SCIENTIFIC INSTRUMENTS

with

Physics News and Views

F. K. RICHTMYER, Editor

Published monthly by the American Institute of Physics in collaboration with the Optical Society of America and the Association of Scientific Apparatus Makers of America.

Subscription price: The United States and possessions, Canada and Mexico, $2.00 per year; foreign, $2.50.

CONTENTS FOR JANUARY, 1935

Volume 6, Number 1

Physics Forum:

Advances in Physics During 1934

Contributed Articles:

Direct Photography of Dust in Air

Sonic Interferometer for the Study of Absorption in Liquids

Construction and Test of an Alternating-Current Bolometer

Precision Radiation Integrator

Technique of Kerr Cells

Variable Capillary Gas Leak

Book Reviews, Physics News
Current Literature of Physics

The February issue will be a Special Number devoted to Industrial Physics

AMERICAN INSTITUTE OF PHYSICS
11 East 38th Street, New York, New York

Please enter my subscription for one year beginning with the January, 1935, issue.

I enclose $2.00 ☐ **(Domestic)**

$2.50 ☐ **(Foreign)**

Please send me a bill ☐

Name.....

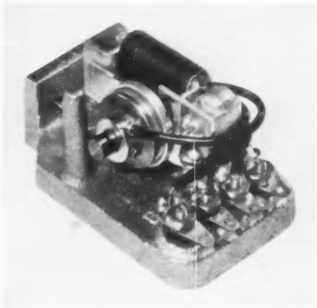
Address.....

.....

I-1-35

"Using CHACE Exclusively"
CRANE
Gas Water
HEATERS
Premier
Keystone
Superior
Automatic shut-off of gas flow to safety pilot-light in America's leading makes of gas water heaters rely upon Chace Thermostatic Bimetal for unfailing performance. Used wherever temperature control is the aim or where automatic action through temperature changes is desired. Varied types of Bimetal are made to suit various problems.
Sold in Sheets, Strips and in Shapes formed to your specifications.
CHACE THERMOSTATIC BIMETAL
"It Bends with the Heat"
W. M. CHACE VALVE CO.
1609 Beard Avenue - - - Detroit Mich

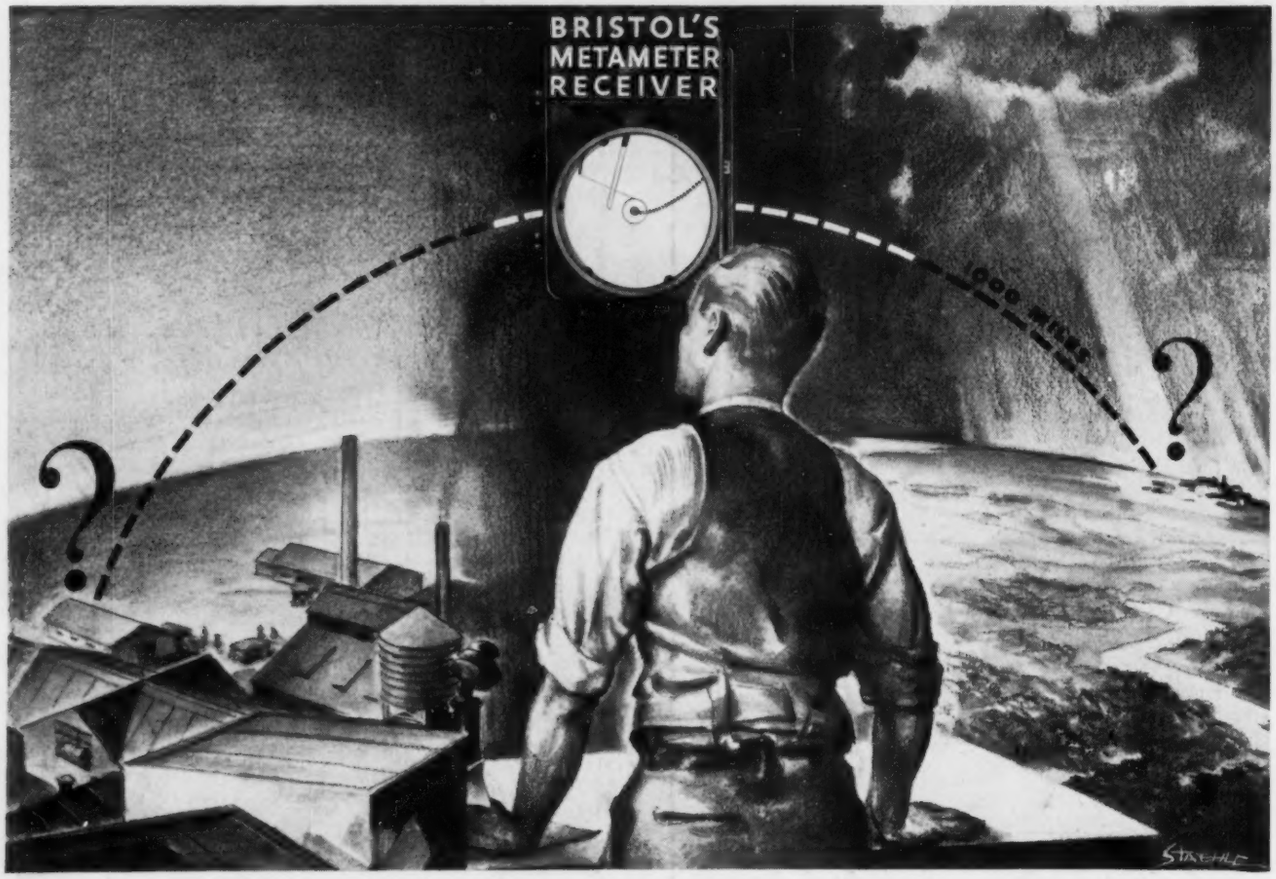
1,000-Cycle Hummer



An inexpensive electromechanical oscillator, suitable as a tone source for bridges or testing equipment. Operates from 4.5-volt battery.

Type 572-A Microphone Hummer.
Frequency 1,000 cycles.
Output 20 milliwatts.
Price $10.00

GENERAL RADIO COMPANY
CAMBRIDGE A **MASSACHUSETTS**



Records what's going on...

on the spot or 1000 miles away!

Are pressures or liquid levels rising to the danger point? Are temperatures changing abruptly, gradually or not at all? How about flow,—or motion?

These are the conditions Bristol's Metameter will help you check not only for processes in your own plant but for operations taking place as far as thousands of miles away.

Consisting of a transmitter at the distant point where the measurement is being made, an electrical circuit for conveying the currents automatically sent out by the transmitter, and a recording instrument at headquarters for continuously charting the currents received, Bristol's Metameter marks a notable progress in telemetering. It operates on the *impulse principle*. The measurements recorded by the receiver are proportional to the *duration* or *length of time* in successive cycles of 15 seconds the impulses flow over the circuit. They are not dependent on the *intensities* or *values* of these impulse currents. So they are not subject to outside interference, distortion, or error. Where available, any existing telephone line may be employed.

The advantages are three-fold. (1) Metameter can be relied on for precision accuracy, (2) Measurements can be telemetered any distance. (3) Only a simple two-wire circuit is needed. For a complete discussion, write for Bulletin 424.

THE BRISTOL COMPANY ~ WATERBURY ~ CONNECTICUT

Branch Offices in Principal Cities Canada: The Bristol Company of Canada, Ltd., Toronto England: Bristol's Instrument Co., Ltd., London, S.E. 14

BRISTOL'S

TRADE MARK REG. U.S. PAT. OFF.

METAMETER

FOR TELEMETERING